

A CONCEPTUAL INFORMATION MODEL (DATA BASE DESIGN) FOR OUTFIT PLANNING

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Final Report

TABLE OF CONTENTS

	Page
1. INTRODUCTION	1
2. BACKGROUND ON THE U. S. SHIPBUILDING INDUSTRY	3
2.1 U. S. Approach	3
2.2 Japanese Approach	6
2.2.1 Japanese Similar-Product Viewpoint	8
2.2.2 In-House Design	8
2.2.3 Japanese Milestone Planning Methods	8
2.2.4 Japanese Production-Oriented Design	10
2.2.5 Procurement in Perspective	10
2.2.6 Process Planning	15
2.2.7 Japanese Assembly-Oriented Production	16
2.2.8 Japanese Outfit Planning	16
2.3 Summary of Functional Differences	17
2.4 Technology Comparison	
2.4.1 Areas of U. S. Lag	21
2.4.2 Areas of U. S. Superiority	23
2.4.3 Technologies Selected	25
2.5 Issues Facing The Government And Industry	25
2.5.1 Government Actions	25
2.5.2 Management of Shipyards	26
2.5.3 The Market	30
3. OUTFIT PLANNING	31
3.1 What is Outfit Planning	31
3.2 Why Outfit Planning	34
3.3 How Outfit Planning is Done	39
3.4 Implementation Approach	42
4. HIGH LEVEL DATA BASE DESIGN MODEL	44
4.1 Definition	44
4.2 Layperson's Explanation of Data Bases	45
4.3 Development of a Conceptual Data Base Design	51
4.4 The High Level Data Base Design Model for Outfit Planning	56

TABLE OF 03 CONTENTS (Cent.)

	Page
4. 4. 1 Contractual Information	57
4. 4. 2 Systems and Structural Planning	61
4. 4. 3 Outfit Planning Information	61
4. 4. 4 Process Planning information	66
4. 4. 5 Part Fabrication Information	66
4. 4. 6 Fabrication, Assembly, and Erection Monitoring Information	69
4. 4. 7 Procurement information	71
4. 4. 8 Overall Model	71
4.5 How to Further Develop and Use a Data Base Design Model	75
5. CONCLUSIONS AND RECOMMENDATIONS	77
5.1 General Conclusions	77
5. 1. 1 Management Attitudes	77
5. 1. 2 Implementation of Improvements	77
5. 1. 3 Improve Areas of Leadership	78
5. 1. 4 Maintain and Improve Standoff Areas	78
5. 1. 5 Recover Areas of Japanese Leadership	78
5. 1. 6 Coordination of Many Advisory Groups	78
5. 1. 7 Taking Advantage of TECHMODs	79
5.2 General Recommendations	79
5.3 Outfit Planning inclusions	83
5.4 Outfit Planning Recommendations	86
5.5 Data Base Design Conclusions	86
5.6 Data Base Design Recommendations	88
5. 6. 1 Develop a Generic Shipyard Data Base Design	88
5. 6. 2 Develop a Company-Specific Data Base Design	88
5. 6. 3 Encourage Development to Occur Individually	88
5.7 Summary of Inclusions	89
REFERENCES	91
APPENDIX: Data Base Design Model Glossary	94

LIST OF TABLES

<u>Table</u>	Page
1 Materials as a Percentage of Costs for Relevant Vessels	11
2 Direct and Indirect Requirements of the U.S. Shipbuilding Industry from 20 Leading Supplying Industries	12
3 U.S. Shipbuilding Support Firms	14
4 Direct Shipbuilding Labor Hours Comparison of United States and Japan	18
5 Direct Shipbuilding Material Cost Comparison of United States and Japan	18
6 Sixteen Most Critical Areas in Shipbuilding Technology	22
7 Areas of Superiority of U.S. Shipyards	23
8 Typical Construction Schedule for Selected Merchant Ships	41

LIST OF FIGURES

Figure	Page
1 Flow of activities in a United States shipyard	4
2 Flow of activities in a Japanese shipyard	7
3 Similar construction methods for a product mix	9
4 Production-oriented zones	13
5 Technology levels of foreign and U.S. shipyards	20
6 Contributions to productivity increases in manufacturing	28
7 Graph of U.S. competitive strategy	29
8 Relationships of material lists to design and to material procurement	37
9 Process plan for part fabrication	46
10 Sample of a work ticket for a fabrication Process	46
11 Filing cabinet analogy	49
12 Individual file drawer	49
13 Individual file	49
14 File relationships	50
15 Entity class relationships	52
16 Relationship of items used in the analogy (Section 4.2)	53
17 Design development cycle	54
18 Entity class symbol for data base design	58
19 Relationship lines for data base design	58
20 Contractual information needed to support outfit planning	59
21 Resolving redundancies	62
22 Systems and structural information necessary to support outfit planning	63
23 Outfit planning/assembly information	64
24 Process planning information necessary to support outfit planning	67
25 Part information to support outfit planning	68
26 Fabrication, assembly, and erection monitoring which supports control necessary for outfit planning	70
27 Procurement information supporting outfit planning in actual production	72
28 Overall conceptual design of a data base design model for outfit planning	73

LIST OF FIGURES (Cont.)

<u>Figure</u>		Page
29	Functional elements of outfit planning	81
30	Planning and scheduling in the management cycle	82
31	Shipyard management via a task work breakdown structure (TWBS)...	84
32	Operations management via a task work breakdown structure (TWBS)	85
33	Shipyard activity wheel	87

1. INTRODUCTION

The objective of this study was to develop a conceptual data base design model (information model) description which details the required functions, information requirements, and data relationships to support outfit planning. This information model defines and relates outfit items to the various material lists, purchase orders, schedules, work packages, work aids, and instructions.

In June 1980, a study entitled "Japanese Technology that Could Improve U.S. Shipbuilding Technology, " was completed and documented for the National Shipbuilding Research Program (NSRP) by the IIT Research Institute. The objective of this project was to identify and examine Japanese shipbuilding technology which requires low capital investment for the U.S. shipbuilding industry to incorporate, but provides high return on investment potential once implemented. One of the methods identified as having the highest potential was outfit planning. A detailed description of outfit planning had already been accomplished in the book, Outfit Planning, published in December 1979, also for the National Shipbuilding Research Program. This introduced the advanced outfit planning approach used and developed by Ishikawajima-Harima Heavy Industries Company, Ltd. (IHI) and other Japanese companies. A definition of the techniques involved, therefore, was not needed; however, a more in-depth understanding of the information environment was required. At present, no U.S. shipyard has fully implemented the outfit planning methods (though some are progressing rapidly), but most have existing material control systems, including programs and other computer-based information systems which may have to be reevaluated in lieu of an outfit planning approach. In this situation, a shipyard considering implementation of outfit planning would benefit by being able to compare their existing systems functions with the data base and methodology requirements needed to support outfit planning.

This study, a conceptual information model (data base design) for outfit planning, has been organized and is intended to be a stand-alone document. It supports the parent document "Japanese Technology That Could Improve U.S. Shipbuilding Technology" by providing a background analysis, Section 2, on the

competitive environment of the shipbuilding industry. This highlights many of the improvement concepts reported in the parent study and establishes the background necessary for understanding the outfit Planning concepts in context with the industry as a whole. Section 3, Outfit Planning, defines outfit planning and the benefits that can be expected from implementing it. Then the data base design model is introduced and defined in Section 4. This is intended to be a high level conceptual or "first cut" view at what the information environment would look like in terms of data base requirements. Conclusions and recommendations, Section 5, will be offered to address the productivity issues of the U.S. shipbuilding industry in general and outfit planning and data base design methods specifically.

The approach taken to this research involved three phases:

- (1) Information collection
- (2) Information analysis
- (3) Final report.

The information collection involved interviews with experts and visits to various shipyards, including Todd Pacific Shipyards and Lockheed in Seattle; Avondale in New Orleans and preliminary project discussions with Ishikawajima - Harima Heavy Industries Company (IHI) in New York. Discussions were also conducted with members of National Steel and Shipbuilding Company (NASSCO) and Bath Iron Works. A large-scale literature search was conducted which identified many documents relevant to the project scope. This information was then analyzed for background information on the shipbuilding industry, outfit planning methodology, and computer data base type information requirements. Once the appropriate background information was established, modeling began on a high level data base conceptual design. After a fully conceptualized information model was completed this document was written and conclusions and recommendations offered as a final section of the report.

2. BACKGROUND ON THE U.S. SHIPBUILDING INDUSTRY

The best way to start a background discussion on the U.S. shipbuilding industry is simply to begin with a functional description of the steps involved in ship production. This will be compared with the Japanese approach and, then, with the technology of all shipbuilding nations. Japan is a good benchmark for a comparison because of its Preeminence in the shipbuilding industry. In 1956, Japan overtook Great Britain as the world's largest shipbuilding nation with 22.1% of that year's market¹ and has been the undisputed leader ever since. In 1981, the Japanese were still the leader with 37% by number of ships, and 50% by gross tonnage, of the market share.² This represents 6 to 10 times the share of their closest competitor. This is not to suggest that they are the only nation worth studying, but certainly they will provide the most insight in a single comparison. The best justification is the fact that they can build a ship in half the time and for half the cost required by a U.S. company.

2.1 U.S. APPROACH

A functional look at a typical U.S. shipyard is shown in Figure 1. The first step in any production procedure is to establish a preliminary design, which is often done by a separate naval architectural firm, and the design, therefore, is usually out of the control of the shipbuilder. The first step for the shipbuilder is usually setting milestones based on the preliminary design and contract specifications. Typical milestones include start dates for fabrication, keel laying, and installation of major equipment (power plant, etc.), as well as launch, sea trial (s), and delivery dates. Although milestones are set at a very general or high level, they are enforced rather strictly, to the point where failing to meet milestones is treated as more important than completing tasks already started in other areas of ship construction.³ Unfortunately, strict adherence to milestones can be an unreasonable obsession because it tends to hamper completion of tasks which may speed up the whole process even though one milestone may fall behind. Often, the reason is simply because progress payments to the shipyard are tied to milestone due dates, which means the customer needs to be educated, as well as the shipyard in terms of schedule control.

SYSTEM
APPROACH

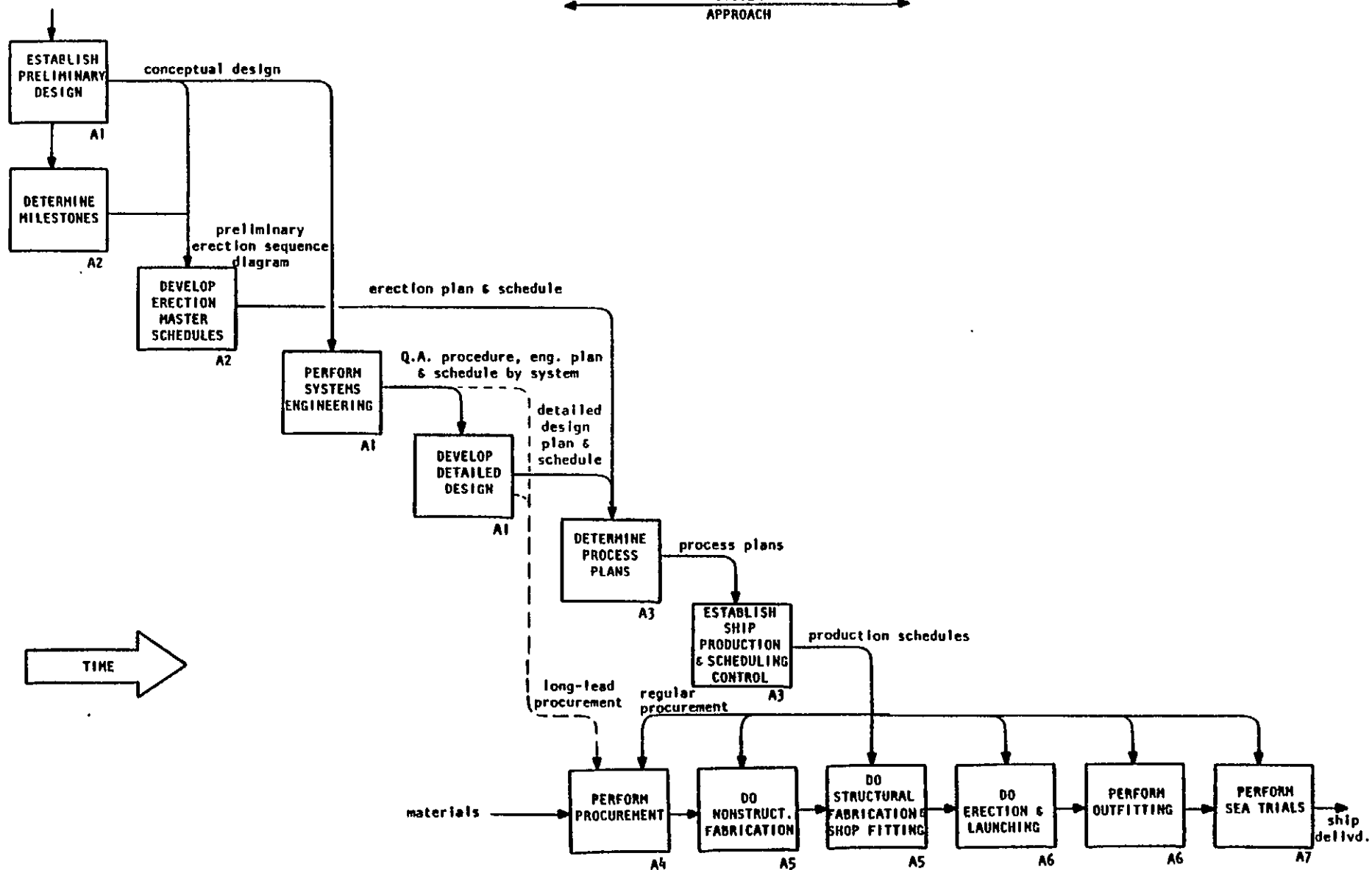


Figure 1. Flow of activities in a United States shipyard.³

The next step is developing the erection master schedule. This is still a very general look at building the ship and is based on the milestones and preliminary design information (i.e., preliminary erection sequence diagrams, etc.) of the erection sequence. The erection sequence is usually broken down into four main sections centering around the hull structure which will eventually contain the main machinery (such as the engine). The hull structure sequence usually involves (1) the machinery area and other significant equipment, (2) the area behind the machinery area, (3) the area in front the machinery area, and (4) the accommodations.

Systems engineering in shipbuilding refers to various systems within the ship such as ventilation, piping, electrical, structural, etc. It involves the planning of engineering activities such as due dates for detail designs, identifying design specifications which affect quality, structural engineering to verify design integrity of the hull, propulsion and machinery systems engineering, electrical and electronic systems engineering, environmental systems engineering, and systems integration. In systems integration, all these separate systems such as piping, ventilation, etc., must run through the ship without interruption or interference with each other or with structural components of the ship.

Detail design of these systems is done to produce the final and most specific drawings of each system. Very little more is needed at this level to understand the detail design activity. These engineering drawings, which are still systems-oriented in U.S. shipyards, will be used in process planning and production.

As the detailed designs are finished, two steps can occur: procurement and process planning. Some early procurement is done during the systems engineering activity such as ordering the main boilers or other main long-lead items, but most procurement in U.S. shipyards begins as the detail designs are in the process of completion since shipbuilders primarily construct or assemble the ship and buy most of their fabricated parts from outside vendors. This implies that detailed fabrication requirements cannot be firmed up until the detail drawings are ready for the vendors to quote on.

Process planning is the responsibility of determining the actual work packages for structural and nonstructural work. Nonstructural work is often divided up by the manufacturing area such as the pipe shop, sheet metal shop,

electrical shop, steel shop, etc. , work packages. Structural work is done at the actual ship construction site. Process planning also establishes the detailed erection plan based on the master schedule and milestones. A partner to the detailed erection plan is establishing the outfitting process. Outfitting in most U.S. shipyards can be defined as the process of adding nonstructural and nonpropulsion items to a ship (e. g., electrical and piping systems, sheet metal and joiner work, paint, etc.) which was, in the recent past, usually done on-board or after erection of the appropriate structural area. Outfitting can be, and is often, done after the ship is launched. A U.S. shipyard will assign work packages of 200 to 2000 man-hours involving a single craft (skill).⁴

Finally, the last "group" of functions involves actual production work. First, all the work packages are scheduled in accordance with the guidelines of the detailed erection sequence. Remember that this is all connected to the original milestones and notice the top-down, one-way direction of the scheduling process. Parts fabrication is a minor part of the actual direct labor costs the shipyard since most fabrication is done by contracted outside sources. Typical in-house fabrication would include structural areas such as steel plate cutting, and nonstructural areas such as piping and/or sheet metal fabrication. More significantly, the direct labor costs are spent in the actual hull and structural erection of the ship. and in major (block) and minor (components) subassembly work.⁵ Much of the subassembly work is done after erection and is, therefore, considered outfitting. Just about as much time is spent in outfitting/ subassembly work as in the actual erection process. Finally, preliminary and final acceptance sea trials are performed to checkout the ship before delivery.

2.2 JAPANESE APPROACH

Instead of going through each function to describe the Japanese approach (see Figure 2),⁶ the following discussion will be geared towards pointing out the differences between the Japanese and U.S. approaches. It should be noted early on that not all U.S. shipyards currently fit the functional description in Figure 1. Many have been slowly incorporating more modern techniques; however, most U.S. shipyards did fit the description in the mid-1970's" and, for the most part, still do today. Therefore, the validity of the following

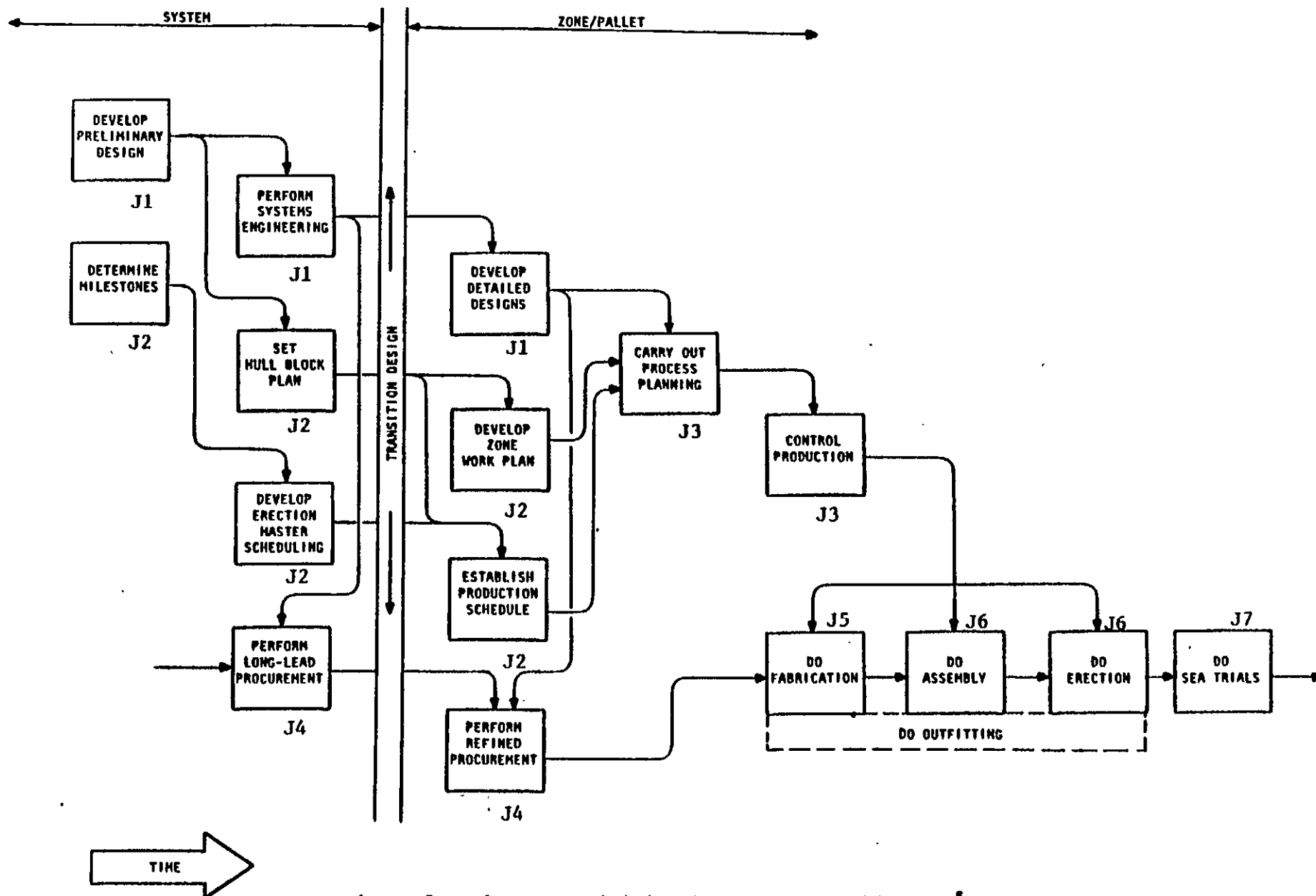


Figure 2. Flow of activities in a Japanese shipyard.⁶

comparison will be high in many instances, at least for general background purposes.

2.2.1 Japanese Similar-Product Viewpoint

The Japanese have acknowledged the assembly or construction nature of shipbuilding, more so than the U.S. industry. To an American shipbuilder, each ship represents a unique product, and it is true that two ships, even if both are of the same type, may have many differences. The Japanese, on the other hand, tend to think of a ship as basically the same product, and it is also true that two ships, even though of different types, have many things in common. This difference in philosophy (and rigorous industrial engineering) has led the Japanese to group the work, assembly processes, components, and gross procurement requirements, by the fairly consistent similarities from ship to ship. The concept is illustrated in Figure 3.⁷ This involves standardization, and the U.S. shipbuilders are making good strides in this area also; but as Figure 3 illustrates, focusing on similarities goes beyond the rigid interpretation of a "standard."

2.2.2 In-House Design

To highlight some of the differences, the Japanese functional flow diagram in Figure 2 shows a bit more detail than the one for the United States. Foreign shipbuilding firms, almost without exception, carry out their own design work. Production considerations can influence design from the very beginning, capitalizing on previous experiences at the shipyards. In the United States, the naval architectural firm conceptualizes the design regardless of the ultimate producer of the ship. This is not to suggest the designs are not as good, just less production oriented. When a specific facility is not considered in the design process, many preliminary design structures/elements may be difficult if not totally impractical for a given shipyard to accomplish. Building to a design created by someone else also makes it difficult to obtain approval for even nonfunctional design changes. Often, various government regulations and procedures also tend to complicate the approval process.

2.2.3 Japanese Milestone Planning Methods

Milestone planning is not much different in Japanese yards; however, the milestone sequence is different. The sequence of major milestones reflects

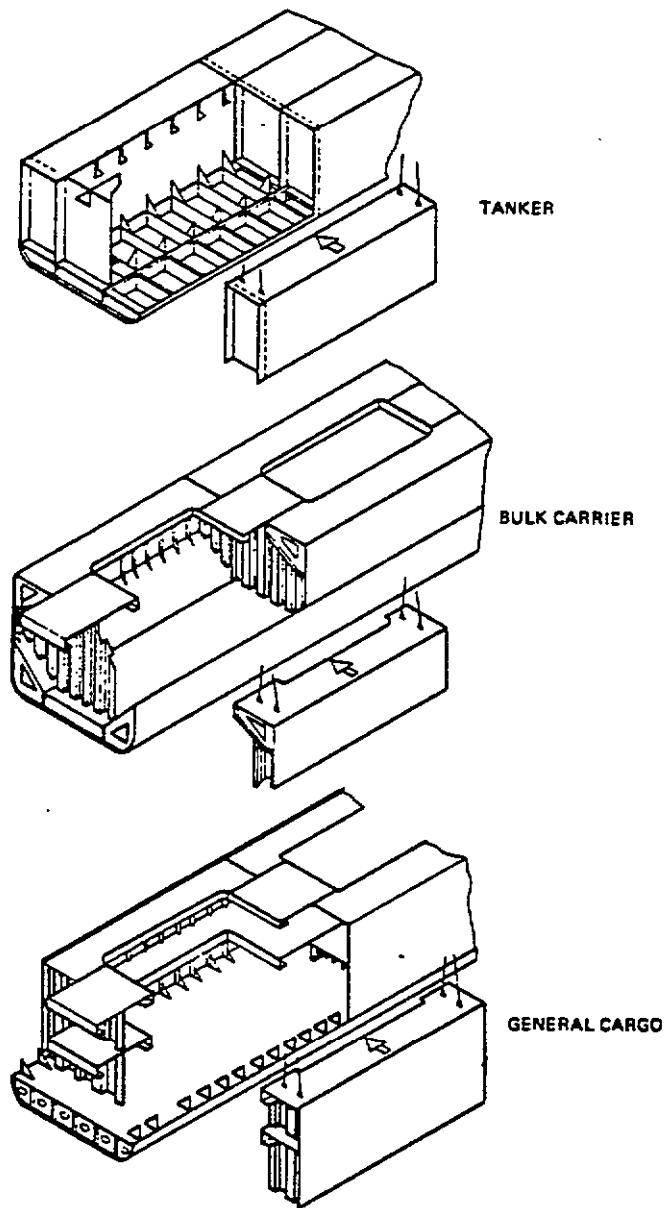


Figure 3. Similar construction methods for a product mix.⁷
 Different ships may have similar construction requirements; the fact that they look different does not mean that production and assembly methods vary significantly.

strategic differences about the overall resource loading on the yard. Japanese and Swedish yards start pre-fabrication and assembly 2 or 3 months before laying the keel.⁴ American yards frequently have the keel laid first, which not only ties up dry dock space longer but also ties up more money in inventory. Also, the Japanese are more flexible about the importance of a milestone. If keel laying should be delayed to do further pre-assembly work, it would be acceptable as long as it improves, or at least does not change, the overall delivery date of the ship. An American firm might decide to pull resources from one area just to make sure an interim milestone is met, this usually tends to disrupt production and can cause expected delays. Again, this is done because progress payments are often tied directly to milestones by customer preference.

2.2.4 Japanese Production-Oriented Design

Systems engineering in Japanese yards is almost exactly the same as in the United States. After systems engineering there is a point of radical departure in the ways the two countries construct a ship. A U.S. shipyard will carry the systems approach through detail design all the way down to production, whereas the Japanese will have a transition design which will translate systems information into various production zones before detail design. The significance of this transition design cannot be overemphasized because it represents what American industries, in general, have been talking about for years but been slow in doing: bridging the gap between design and production planning. Essentially, the ship is broken down into main production zones (Figure 4)⁸ such as machinery or accommodations, and then these zones are broken down further into "areas" or pallets of similar work. Similar work does not mean similar worker skills, as it usually does in America; it usually means a similar level of effort such as the work three men can accomplish in 1 week. This transition design, often called product work breakdown structure (PWBS),⁹ is explained at length in several books (see the References in general), but the significance is that the design department is heavily involved in production planning.

2.2.5 Procurement in Perspective

Materials usually account for over 50% of the cost of a ship, Table 1. Even though this can represent close to 3 billion dollars to supplier industries in America (Table 2), shipbuilding is seldom a major part of a sup-

TABLE 1. MATERIALS AS A PERCENTAGE OF COSTS FOR RELEVANT VESSELS¹⁰

<u>Type</u>	<u>Materials, percent of costs</u>
Naval	
Auxiliary	59
Amphibious	53
Surface Combatant	55
Submarine	38
Hydrofoil	35
<u>Merchant</u>	
General Cargo	48
Tanker (87,000 DWT)	52.5
Tanker (265 DWT)	45
Roll-on/Roll-off	51.5
LASH (Lighter-Aboard-Ship)	50.5
Container	50.5
LNG (Spherical) (Liquid Natural Gas)	59.5

TABLE 2. DIRECT AND INDIRECT REQUIREMENTS OF THE U. S. SHIPBUILDING
INDUSTRY FROM 20 LEADING SUPPLYING INDUSTRIES¹¹

Supplying Industry	Shipyard Industry Requirements, millions of dollars
1. Primary Iron and Steel Manufacturing	\$422.7
2. Primary Nonferrous Metal Manufacturing	280.0
3. Heating, Plumbing, and Fabricated Metals	228.5
4. Wholesale and Retail	218.2
5. Engines and Turbines	180.9
6. General Industrial Machinery	168.5
7. Other Transportation	128.1
8. Business Services	124.2
9. Other Fabricated Metal Products	117.9
10. Real Estate and Rental	80.5
11. Electric, Gas, Water, and Sanitary Services	75.1
12. Metal working Machinery and Equipment	64.8
13. Lumber and Wood Products	61.3
14. Finance and Insurance	57.1
15. Electrical Transmission Equipment	57.0
16. Motor Vehicles and Equipment	54.1
17. Business Travel	50.6
18. Maintenance and Repair Construction	44.9
19. Machine Shop Products	43.4
20. Stone and Clay Products	39.9

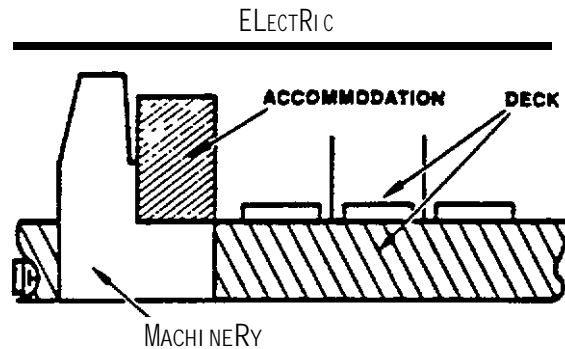


Figure 4. Production-oriented zones. ⁸ Design organized in terms of the similarity of problems encountered in these zones leads to increased efficiency. These initial design zones are common to all ships. Deck design includes everything that is not in accommodation or machinery design. Electric is rationalized as permeating all others.

plier's business. Suppliers are well diversified and primarily service other industries where demand is more predictable. Since demand for ships is very uncertain and construction time can take 1 to 3 years for any given ship, suppliers really cannot depend heavily on the shipbuilding industry for a constant income. In fact, the U.S. shipbuilding orders usually represent less than 1% of any particular supporting industry's output except for steel plate, which is about 16%.¹⁰ In Japan and Europe this does not appear to be the case. In fact, there appears to be a much healthier (in terms of competition) situation just in terms of the number of suppliers available for a given item, as illustrated in Table 3. There would need to be more information to suggest why this situation exists, but the net result is a low leverage situation for American shipbuilding firms. This is a procurement factor when the producer has no leverage, and it tends to increase material prices and lengthen the lead times necessary to manufacture a product. The Japanese seem to be more

TABLE 3. U. S. SHIPBUILDING SUPPORT FIRMS¹⁰

Component Category (NAVSHIPSO) and ISSD	Number of Firms Listed	
	U.S.	European and Japanese
Air Conditioning Plant	3	26
Anchors	0	15
Bearings, Stern Tube (Large)	1	15
Bearings, Thrust (Large)	1	14
Boilers, Auxiliary	3	18
Boilers, Main	5	14
Cable, Electric	3	28
Chain, Anchor	1	20
Compressors, Air	4	34
Condensers	1	11
Consoles and Control Equipment, Bridge	3	24
Consoles and Control Equipment, Central	4	26
Cranes, Deck	3	24
Gears, Reduction	4	24
Generator, Electric, Diesel	3	51
Generator, Electric, Gas Turbine	4	7
Generator, Electric, Steam Turbine	2	6
Hydraulic-Power Equipment	1	22
Motors, Electric	5	29
Propellers, Fixed Pitch	1	20
Propellers, Control Table Pitch	1	25
Pumps, Fuel Oil	5	23
Bilge	2	23
Lube Oil	2	20
Sewage Treatment, Equipment (Package Unit)	4	17
Steering Gear	1	17
Switchboards	4	52
Valves	2	118
Winches	4	33
Windlass	2	26
Subtotal All Categories--Unique Firms	(50)	
Engines, Diesel		
Above 750 through 1600 BHP	6	66
Above 1600 through 3600 BHP	4	32
Turbines, Main Propulsion		
Gas	4	
Steam-Nonnuclear	3	

organized in terms of ordering all materials earlier in the manufacturing process whereas the United States concentrates mainly on long lead time materials. Part of the reason is that they start with assembly work of nonstructural areas before keel laying (structural work) which means a major portion of their detail drawings, which are necessary for ordering fabricated parts, are done earlier. However, even before detail drawings are released, procurement of many items is already in process. The Japanese will already have contracts set for time-phased delivery of an estimated amount of items. If they do not know the exact time, they will give the vendor at least the material and rough features of the part. They have done a much more thorough job of standardizing their component parts as well as the "nature" of their assemblies. This is another point of philosophical difference between the Japanese and American yards.

2.2.6 Process Planning

The Japanese spend more time on design as a Percent of the overall ship construction than the United States does; however, as a result of this, they spend less time in the actual construction.

, Production scheduling can actually begin concurrent with detail design because the transition design has converted the ship systems information essentially into production groupings based on the length of time it takes to perform the tasks. Since design is linked to time this early on, there is more information available to begin the scheduling activities even before formal process planning. In this sense, process planning really involves coordinating the information from detail design and scheduling to generate the work packages. In Japan these work packages usually consist of a detailed drawing of the work to be done and special instructions only. Since the tasks are grouped into similar zones and areas from ship to ship, the workers really do not need detailed step-by-step instructions with each work package. Also, how the workers perform the task is usually up to them and their foreman as long as it meets specifications. However, detail design and process planning in Japanese shipyards do involve some more tedious tasks. Since the approach tends to be more assembly or pre-outfitting oriented than in the United States, more fixtures and production aids must be developed to assist in building these units and to hold them together before actually assembling them to the main structure.

2.2.7 Japanese Assembly-Oriented Production

When it gets to the actual production activities, personnel will usually work in groups of two to four people using the plan-do-see method.⁵ The equivalent of a foreman will manage several of these groups. The work is divided up into what that group can accomplish in a week and the components are all together on a pallet for them to work with. Plan-do-see involves about 1 to 4 hours per week for the group to figure out or plan their best approach to the work, the remainder of the week to do it with minimal guidance from the supervisor, and a few hours at the end of the job to evaluate and feed back changes which should be incorporated for future work. This is rather like letting a whole production facility operate on 3-person, do-it-yourself kits with an informal mechanism for feedback on how well these kits were planned.

2.2.8 Japanese Outfit Planning

Also, as can be seen in Figure 2, outfitting or what the United States often calls pre-outfitting, happens all throughout the actual construction of a ship in Japan.

"Outfitting has long been a time consuming process and an extremely expensive portion of the overall construction cost. Concentrated in the last stages of the building process and usually done at a wet dock, the physical effort required to put each item on board the vessel, move it into place, install it in the proper location, and test it required unnecessarily large amounts of manpower, staging, and time. To reduce the large use of manpower and to save time, current procedure is to pre-outfit or modular-outfit new ships. This takes maximum advantage of the ready access to portions of the ship during early assembly stages for the relatively sturdy outfit, such as piping, electric cable, machinery, electrical and electronic equipment, and furnishings all are installed before an assembly is placed

Pre-outfit planning and the pre-outfitting procedures are synonymous with production-oriented planning and assembly procedures in other industries. It is a major contributor to the view that shipbuilding can take advantage of the economies associated with the application of disciplined industrial engineering practices.

2.3 SUMMARY OF FUNCTIONAL DIFFERENCES

The Japanese can build a ship in approximately half the time it takes an American company and at about half the cost. This is a phenomenal difference which can be attributed mostly to the heavy emphasis on overall application of design and manufacturing engineering methods and better management of labor and resources. As a point of national pride, it may be of interest that Japan owes a good deal of its success to American methods which were instituted by National Bulk Carriers, Inc. (NBC) of New York. NBC produced ships in a former Japanese Navy shipyard at Kure in 1952. They pioneered assembly line methods and pre-fabrication of large sections for big tankers and bulk carriers.¹ The rest of the credit, unfortunately for the United States, is totally with Japan and their superior application of engineering and management methods.

Table 4 is a comparison of direct shipbuilding labor hours in the United States and Japan as a percent of total time spent based on a similar ship design. (Note: This can be directly related to the functional diagrams in Figures 1 and 2.) The Japanese spend more time, relatively speaking, in design/engineering, process planning/production control, materials procurement and sea trials (testing). They spend less time in scheduling/planning, fabrication, and construction than the United States. Based on the previous discussion of functional differences, this tends to support the belief that the Japanese focus more of their efforts on planning and, therefore, need less time in production than the U.S. yards. This does not suggest that the Japanese spend more time in these areas, in an absolute sense; in fact, the ratio of total labor hours of the United States to Japan shows that the United States spends about three times as much effort overall. This may suggest that the Japanese philosophy of looking for the similarities in planning and construction has put them much farther along the learning curve for any given ship than the American unique product approach. They are definitely more productive with their labor resources, at any rate.

Table 5, direct shipbuilding material cost, compares the relative emphasis each country puts on materials. Japan again has larger percent cost in design and engineering materials and less in construction materials, a distribution which tends to support their production-oriented design emphasis. Perhaps a more significant comparison, however, is the ratio of total material costs. American shipyards are spending almost 50% more on materials than the

TABLE 4. DIRECT SHIPBUILDING LABOR HOURS COMPARISON
OF UNITED STATES AND JAPAN¹²

Shipyard Flow of Activities	Percent of Total Time	
	United States	Japan
Design/Engineering (A1, J1) ^a	4.6	14.0
Schedule/Planning (A2, J2)	1.3	0.9
Process Planning/Production Control (A3, J3)	1.8	2.8
Materials Procurement (A4, J4)	0.5	2.0
Fabrication (A5, J5)	60.6	52.0
Construction (A6, J6)	30.8	27.5
Sea Trials (A7, J7)	0.4	0.8
Total (A, J)		100.0

Total Labor Hours Ratio: United States/Japan = 3.08.

^a A - related to Figure 1 activities; J - relates to Figure 2 activities.

TABLE 5. DIRECT SHIPBUILDING MATERIAL COST COMPARISON
OF UNITED STATES AND JAPAN¹²

Shipyard Flow of Activities	Percent of Total Cost	
	United States	Japan
Design/Engineering	4.8	10.4
Schedule/Planning		
Process Planning/Production Control		
Materials Procurement		
Fabrication	72.1	74.3
Construction	23.0	15.2
Sea Trials	0.1	0.1
Total	100.0	100.0

Total Material Cost Ratio: United States/Japan = 1.45.

Japanese. This is largely due to Japanese shipyards being in a buyer's market as opposed to the United States seller's market. It is also due to Japan's procurement emphasis and relations.

2.4 TECHNOLOGY COMPARISON

The previous section (2.3) discussed functional difference in United States and Japanese shipyards; the purpose of this section is to look at the American application of technology relative to Japanese and European shipyards. A good starting point would be to destroy a few myths about Japanese shipyards so that the technology comparison can be developed without misconceptions.

Many people are still hold the false assumption that the Japanese shipyards were destroyed during World War II (as those of Germany and the Netherlands indeed were), and that this gave them a tremendous opportunity to rebuild and modernize. The truth is that almost every Japanese shipyard escaped bombing during the war, even the Mitsubishi shipyard in Nagasaki was intact. It is not known if this was intentional or not, but several shipyards survived in heavily bombed-out areas; certainly the wartime reasoning for not bombing them is unclear. So the Japanese were, at best, on equal footing with the United States and possibly slightly worse off since most of their shipyards were turn-of-the-century vintage and for many years after the war they were restricted to salvage, repair operations, and fishing boats. It was not until 1949 that they were allowed to export, ships and by 1956 they displaced Great Britain as the number one shipbuilding nation of the world.¹ It is not known how well the German and the Netherlands shipyards were rebuilt in a war-devastated economy; however, the end of World War II was 37 years ago. Any arguments of unfair advantages because of the war has to be questioned.

A technology survey contracted by the Maritime Administration in 1978 provides an in-depth technology comparison of U.S. shipyards and world position.¹³ The United States was ahead in only one of eight major shipbuilding categories., Figure 5. Technology levels were ranked such that 1 = fair, 2 = good, 3 = better, and 4 = best with the criteria of each category being related to the state-of-the-art for that topic area.

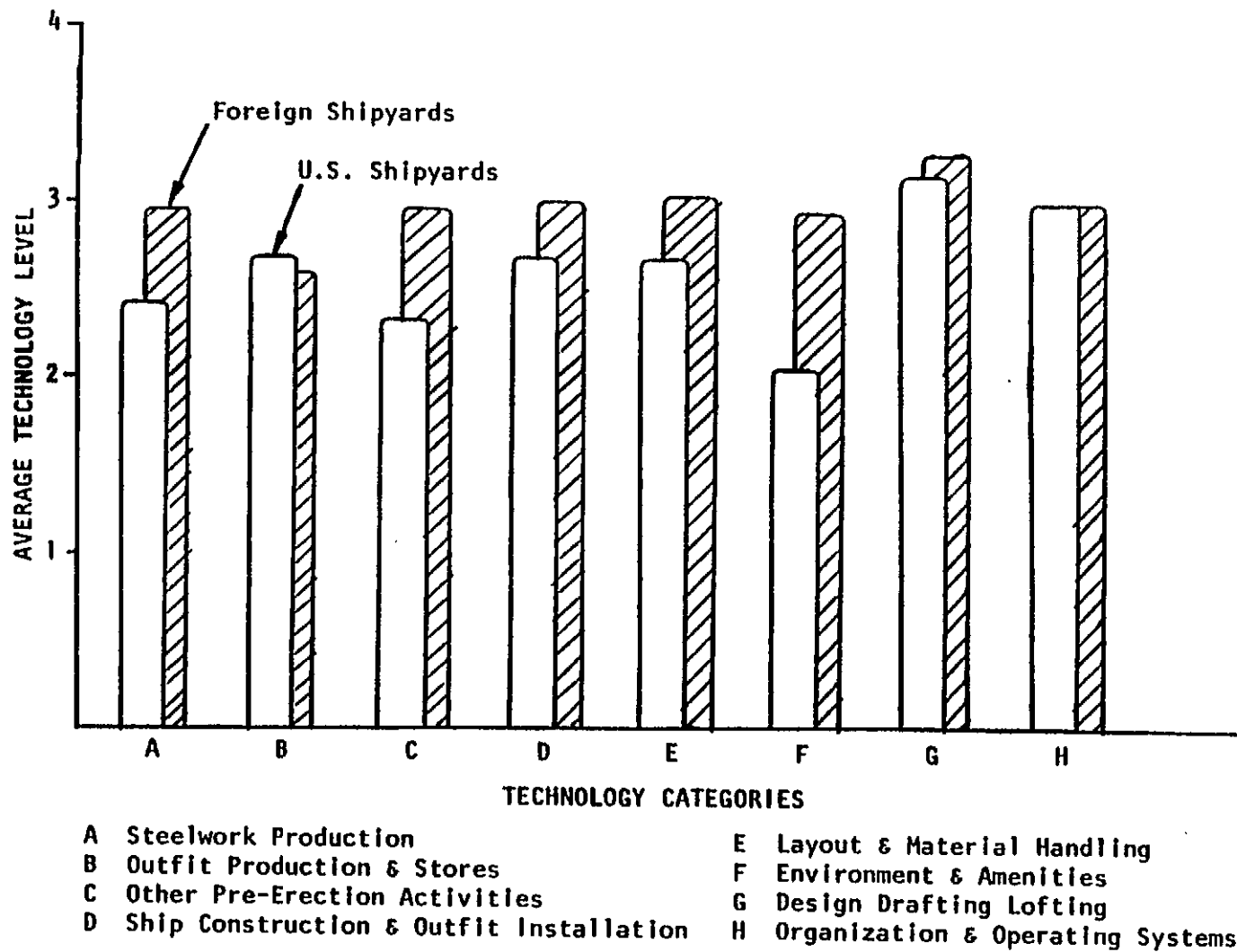


Figure 5. Technology levels of foreign and U.S. shipyards.¹³

2.4.1 Areas of U.S. Lag

First, looking at the areas in which the United States is behind, pre-erection activities more than any other category identifies the high-technology shipyards. Ironically, this is exactly where the United States scored the worst in an absolute and relative sense to other shipyards. Looking closer at the sixteen most critical areas, Table 6, subcategories C1 through C4 show the deficiencies in more detail. It is not that the United States is totally void in the pre-erection activities, there are several isolated instances where the United States has applied modular construction. Quarter modules (accommodations) have been lifted onto ships as a whole unit right down to the mattress and linens with plumbing and electrical facilities ready for hook-up.¹¹ Some shipyards such as Lockheed,¹⁴ Ingalls, and SEATRAN⁴ have applied modular construction techniques to hull sections. However, there are only a few U.S. companies currently where pre-outfit planning is being carried out through the design and planning stages as was **the** case with the Japanese (refers to functional comparisons). More American shipyards are now considering it, which at least is a good sign.¹⁵

The implications of pre-outfit planning or assembly orientation to design have already been seen in the functional comparison; however, the following quote discusses its implication in the technology rankings:

"Design Drafting Production Engineering and Lofting, Category C: In ship design the difference is largely explained by the fact that some U.S. yards use outside naval architects and consultants rather than having in-house facilities as found in all the foreign yards, surveyed. This does not necessarily impair the efficiency of the design function, although it may be one of the reasons why the design for production and production engineering ratings in the U.S. yards were lower than their foreign counterparts. Design for production needs to be applied not only at the initial design stage but right through design development and detailing. This can be achieved only when all the relevant shipyard departments believe in the benefits of production-oriented design and apply it with conviction and persistence. "¹¹

Production-oriented design depends heavily on production and industrial engineering. Production engineering is scattered in most U.S. shipyards and less development is being given to assembly, outfitting, and erection standards, practices, and sequences than other countries. Japan is probably the

TABLE 6. SIXTEEN MOST CRITICAL AREAS IN SHIPBUILDING TECHNOLOGY¹³

Elements	Level Difference, Foreign Higher than U. S.
c1 Module Building	1.1
C2 Outfit Part Marshalling	0.6
C3 Pre-Erection Outfitting	0.5
D2 Erection and Fairing	0.8
D4 On-Board Services	0.6
D8 Hull Engineering	0.6
G1 Ship Design	0.7
G6 Production Engineering	0.7
H1 Organization of Work	1.0
A6 Subassembly	0.9
A8 Curved Unit Assembly	0.6
A9 3-D Unit Assembly	0.8
D3 Welding	0.6
F1 General Environmental Protection	0.7
C4 Block Assembly	0.9
D1 Ship Construction	0.8

The letter prefixes relate to the major categories in Figure 5. Module Building, Outfit Part Marshalling, Pre-Erection Outfitting, and B1 Block Assembly are all subcategories of C, Other Pre-Erection Activities. Note: If Module Building is 1.6 for U. S. shipbuilding, then the average for other countries must be 1.1 more than that or 2.7.

extreme opposite of this policy. "About 200 university naval architecture and 500 engineering graduates enter the Japanese shipbuilding industry every year. "I In the United States there are only a handful of universities that even offer naval architecture, and most other engineering graduates probably do not even consider a career in shipbuilding as a viable alternative. Furthermore, many naval architecture graduates go into research and development or to naval architecture firms specializing in ship design. There are very few new engineering graduates of any kind that start employment at a shipyard. In addition, naval architects that are hired right out of school may never see or contribute directly to actual production work because of the need for their expertise in systems engineering.

2.4.2 Areas of U.S. Superiority

The U.S. shipyards do have some areas which are technologically better than other nations, Table 7. These are more of a consolation than an indication of competitive edge, but it is important to understand these areas in order to exploit them. Unfortunately, plate cutting, auxiliary storage, and steel work coding are technologically better because the United States tends to have extremely high work-in-progress inventory, especially in steel which can represent over half of the total material cost.¹¹ The Japanese typically

TABLE 7. AREAS OF SUPERIORITY OF U.S. SHIPYARDS¹³

Elements		Level Difference, U.S. Higher than Foreign
A3	Plate Cutting	0.3
B11	Auxiliary Storage	0.6
D13	Testing and Commissioning	0.7
G4	Steel working Coding	0.4
G5	Parts Listing	0.5
H3	Steel work Production Scheduling	0.5
H8	Outfit Production Scheduling	0.3
H9	Outfit Installation Control	0.4
H10	Ship Construction Control	0.6

Note: The letter prefixes relate to the major categories of Figure 5.

only have 3 to 4 days worth of steel on hand at any given instant;¹⁶ their vendors carry the inventory or produce to deliver in small lots. The United States excels in the areas of cutting, storage, and coding possibly to their own detriment.

It is interesting to note that the United States has superior scheduling and controlling methods as well. This again is an anomaly of technology. The high rating comes from more sophisticated computer programs as indicated in the following quotation:

"The point which was of great concern in this part of the work [Organization and Operating Systems] related to the difference between cost and budgetary control and production control. The problem basically is as follows: Most yards appear to have soundly based recording and control systems, some of which will use fairly advanced computer systems and look very impressive. These systems do not, however, of themselves, improve production scheduling which would result, for instance, in improved machine loading packages to score a Level 4. What U.S. shipyards do need are competent teams of industrial engineers and work analysts dedicated to the detailed planning of work at the shop floor level."¹³

In other words, the United States has good controls; however, there is little evidence that the first line supervisor is using or even can use them to direct the workers.

Even if the scheduling systems were being used all the way to the direct laborer, there is some question about how effective they would be. There are four levels in U.S. scheduling which are top-down (directives from upper management) and one-way (go on down the rank unquestioned). Rung 1 is key events, hull erection and systems schedules; rung 2 is block assembly and subsystem assembly (by shop); rung 3 is operation sheets and outfitting; and rung 4 is the actual production schedules. The theory is "... a carefully disciplined, one-way system keeps the more detailed, but smaller-scaled subordinate schedules in harmony with the rest."¹⁷ In actual practice, however, the top rung is dealing with very general and limited information. Because of this they must build in certain allowances for error (or shop) and this gets perpetuated throughout the subsequent levels. The schedules are issued, except at rung 4, without any intention of being changed resulting in schedules which do not reflect the most streamlined and efficient ways of doing work.¹⁷ If the systems were to be modified to more of a closed-loop, feedback-oriented

system the United States might just be able to capitalize on this area. Otherwise, if the "control systems" are used more for record keeping, then the amount of technological advantage the U.S. has in this area will not serve any useful purpose.

2.4.3 Technologies Selected

Certainly not all the technology issues have been discussed. Technologies have been selected to provide a macro look at some of the major technology issues; however, for a more in-depth treatment of technology issues the best sources are the "Technology Survey of Major U.S. Shipyards" (Ref. 13), "The Shipbuilding Industries of the U.S. and U.S.S.R. as a Basis for National Maritime Policy: Current Capabilities and Demand Potential" (Ref. 14), and "Personnel Requirements for an Advanced Shipyard Technology" (Ref. 11).

2.5 ISSUES FACING THE GOVERNMENT AND INDUSTRY

The dilemma that the U.S. shipbuilding industry and U.S. policy makers have to face boils down to incentives. Currently, there is little incentive for the U.S. shipbuilding industry to modernize. It is really a combination of three factors, which are governmental overprotection and overregulation, conservative managerial policies of the shipyards, and the current world-wide slump in the demand for ships.

2.5.1 Government Actions

The government has taken the course of overprotection in shipbuilding. While most countries at some point or another have subsidized their shipbuilding industries, none have done it so outrightly against free-market theories as the United States. Other countries chose to provide low interest loans, accelerated depreciation on capital equipment, tax deferred capital gains, tax-free revenue funds, restriction of ship imports, duty-free material, cargo preferences, and cabotage restrictions. Most of these encourage capital investment and do not directly tamper with the free-market price. Meanwhile the U.S. government used direct subsidies, ship financing guarantees, tax-deferred capital construction funds, limited cargo preference, and cabotage.¹¹ The most emphasis was placed on direct subsidies and financing which meant not only tampering with the market price, but also entering into negotiations with the end buyer. Why improve shipbuilding productivity when the government is

going to make up the difference¹⁸ and other shipyards are also satisfied with the status quo?

Besides intervention with the merchant marine, the government has also continued to supply very few incentives to modernize on the defense end. Most defense contracts, and Navy contracts are no exception, provide very little encouragement to modernize.¹⁹ There are several variations, but most defense contracts are either some form of fixed fee/profit, or fixed price. A fixed fee is used often in aerospace and military vehicle production.²⁰ The problem with this kind of contract is that it usually is not multi-year commitment so the manufacturer bids on current capabilities (to get the lowest production costs for the bid) and does not modernize much during production. If the manufacturer does modernize and starts producing the item cheaper, thus increasing profits, a government audit will adjust the profit structure back to the fixed profit rate. This means the manufacturer will have to bear the total burden of the new capital equipment. The Navy has primarily used some form of fixed price contracting which also has problems.^{10, 19} Fixed price contracts also encourage the bidder to estimate costs based on current facilities to get the lowest production costs possible for the bid. Theoretically, the shipyard could plan modernization into the bid; however, this brings the price up. Also, the contracts tend to be for only one or two ships so there is no reason to modernize during production. Another related problem is government payment schedules, which are usually linked to traditional milestone schedules. Pre-outfitting, if incorporated, will call for a different milestone sequence and increase shipyard flexibility, but payment schedules must also adapt.

2.5.2 Management of Shipyards

It is really difficult to rationalize the current situation of the U.S. shipyards.

"During the past 30 years, this country [in terms of U.S. shipbuilding] has contracted to a fraction of its former size and has only in recent years made substantial investments in new facilities. On the other hand, foreign shipbuilders, notably the Japanese, have invested billions of dollars since World War II in new facilities and can now produce merchant ships in much shorter time and with substantially fewer man-hours than are required in the United States.

Other countries seem to fit the productivity model which suggests that capital and technology are the most effective means to improvement, Figure 6.²¹ There was every reason to expect the U.S. shipbuilders to follow the same pattern. Even though overprotected by the government, they were still competing effectively on a world market in the 1950's, and internally the 12 "key" shipyards^{10, 13, 22} were all non-diversified companies. This, on the surface, would suggest that the U.S. shipyards would be trying to gain the competitive edge for domestic and international business. As it turns out, the U.S. posture seemed to be more one of survival than competition. Very few new companies have come into the shipbuilding scene since World War II, and very few have dropped out. The graph of competitive strategy, Figure 7, is a qualitative attempt to explain the industrial strategy. As discussed in the functional comparison, the United States is just now changing its philosophy of constructing a ship by systems. Also, "widespread adoption of the new techniques implies the substitution of large capital outlays for those on labor, limiting the ability of the yards to tailor costs to levels of demand by adjusting the size of the labor force. This flexibility has been highly prized by the industry in the past, and has been a factor in delaying such innovative methods."¹⁰ Very minimal investments in facilities and equipment resulted from this philosophy.²⁰

By the 1960's this survival mode had many shipyards in pursuit of defense work because, even with government subsidization of commercial shipbuilding, the United States was becoming less and less competitive. It really then becomes a question of national security. "The question for shipbuilding boils down to one of deciding whether the nation should retain the ability to build its own Merchant Shipping. National security is the ultimate justification on which the question hangs. A key ingredient of national security is the Merchant Marine."²² So not only is management conservative in the 1960's, but U.S. policy begins to view shipbuilding from a national security point of view, which forewarns of further government interference and, even worse, the shipbuilders are becoming heavily dependent on defense contracts which give them little incentive to modernize. Much could be said on the nature of defense industries, but it is sufficient to say that they are generally unresponsive to the changing state-of-the-art technology as many commercial manufacturers need to be--at least, eventually--to survive.²³

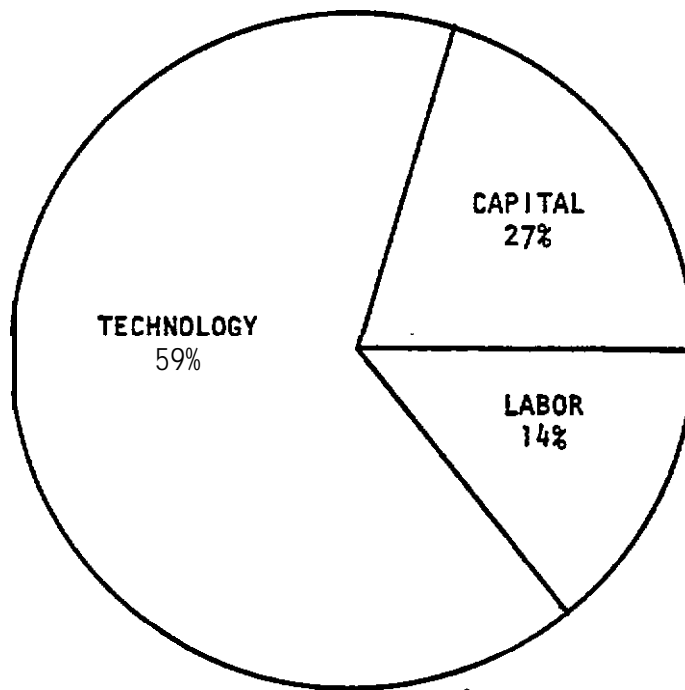


Figure 6. Contributions to productivity increases in manufacturing.²¹
This represents the average of three separate estimates of contributions of factors to productivity increases. These studies were conducted by Denison; Kendrick; and Christensen, Cummings, and Jorgensen. There is a strong tie between technology, labor, and capital, so any one factor cannot be totally separated from the others.

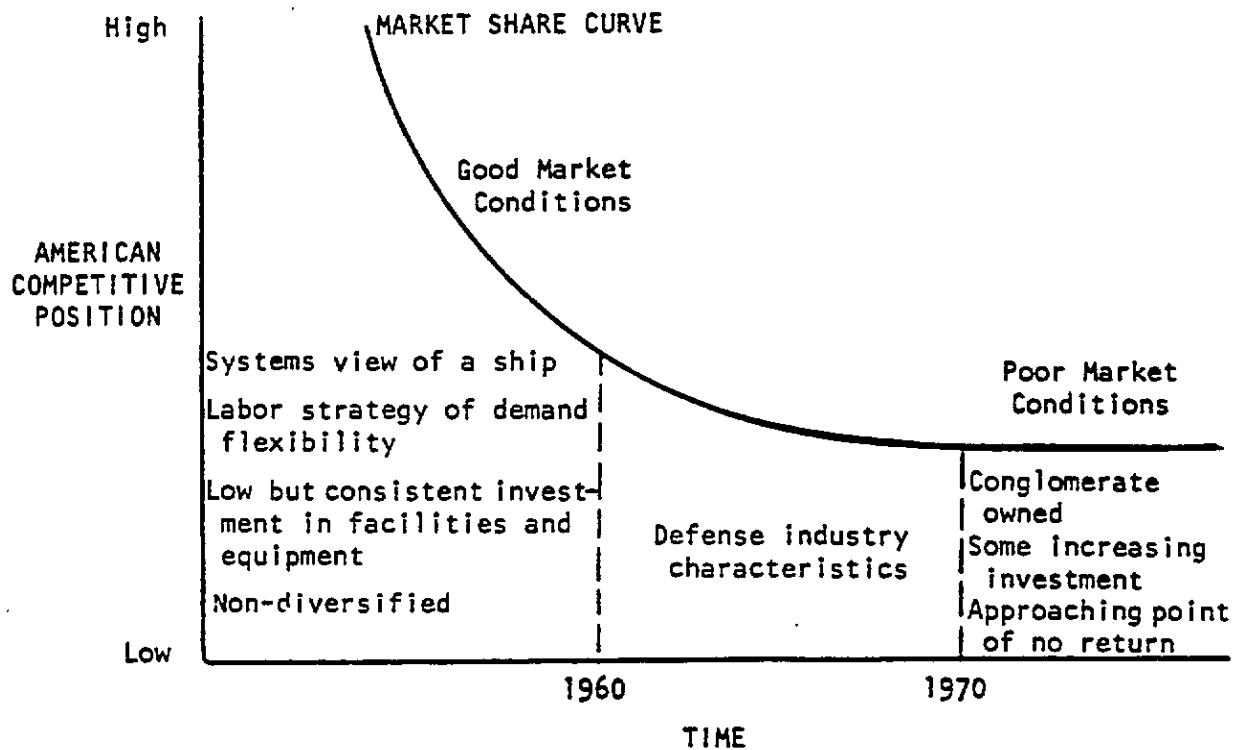


Figure 7. Graph of U.S. competitive strategy.

Mostly in the late 1960's and early 1970's these privately held shipyards were purchased by conglomerates with the exception of Bath which did the reverse by purchasing a conglomerate.²⁰ This could be good or bad. So far it seems to have been good, to the extent that new management has taken over. Contrary to some shipyards' belief, "the skills required in (these) administrative, financial, and personnel functions are virtually identical to those required in similar functions in other manufacturing industries,"¹¹ whereas many shipbuilding companies have been and still are "managed by hardware-oriented production men."¹⁰ Why would conglomerates require an industry in such bad shape? For one reason, because of the undercapitalized conditions of most yards, they could and did buy into the industry relatively cheaply (all but one was purchased for under \$15 million)²⁰ and because shipyards, even though marginally profitable, have very favorable cash flows.¹⁰ The reason conglomerate purchase of the shipyards could be construed as bad is the multi-product nature of a conglomerate. Not being committed to just one product, good management might dictate taking the good cash flow of the shipyard and investing it in an area that has a large return which, of course, would not be shipbuilding's 6% profit margin.^{10, 11, 20} So far, this has not been the case, and it looks as though many shipyards are getting serious about modernizing.

2.5.3 The Market

Even if companies are planning on modernizing, the present may not be the opportune time to support large capitalization. The market is in a severe slump, and orders are down for all countries. Currently, a contract of one or two ships in an under-capacity yard does not motivate or justify change.²⁴ As much as the conservative management style is restrictive to change, it is right about one thing: the Japanese approach to capital-intensive special equipment is particularly susceptible to a long downturn in the market, since the capital costs must be carried even when business is lacking¹¹ (whereas labor can be laid off). In fact, 43 Japanese shipyards had gone bankrupt by the end of 1979.²² However, it should be remembered that the slump in the late 1940's provided Japan with the time it needed to reevaluate their approach to shipbuilding which catapulted them into world dominance within 8 years.¹ This might, therefore, be the best time to for a recovery.

3. OUTFIT PLANNING

As has been shown in the background information on the U.S. shipbuilding industry, the overall goal is to increase the integration of design, material procurement, and production planning and control in ways that improve Productivity and result in an improved competitive Position. No one technique or method will bring this integration about, only the planned implementation of several techniques backed **up** by rigorous industrial engineering and top management support will effect on overall change. Many differences in U.S. and foreign shipbuilding techniques have been discussed, and while all must be considered important to any overall implementation plan for productivity improvement, the rest of this paper will focus on the one method identified as potentially the most useful single improvement, outfit planning.

3.1 WHAT IS OUTFIT PLANNING

Traditionally, the American shipyards have classified two types of outfit planning, outfitting and pre-outfitting. Outfitting is the process of adding nonstructural and nonpropulsion items to a ship (electrical and piping systems, sheet metal work, paint, etc.). Pre-outfitting is the installation of pipe, cable, ventilation equipment, foundations, and components within a unit or module prior to erection.¹¹ The distinction is that outfitting occurs on board the ship and pre-outfitting is on-block (module) or unit work that can occur in parallel with other ship construction activities. For all intents and purposes, this traditional distinction between outfitting and pre-outfitting is only an artificial one and the two should not be considered as unique planning tasks apart from each other. Therefore, the term outfit Planning applies to all nonstructural planning and production work.

The following are excerpts from the parent document, "Japanese Technology Which Could Improve U.S. Shipbuilding Productivity,"⁸ which further defines and explains the concepts of outfit planning.

- Outfit planning is a term used to describe the allocation of resources for the installation of components other than hull structure in a ship. Methods applied in Japanese shipyards have produced such benefits as -

1. Improved safety
 2. Reduced cost
 3. Better quality
 4. Shorter periods between contract award and delivery
 5. Adherence to schedules.
- Three key features of the methodology are that the outfit design and planning functions are intimately linked, that they are linked because their principal product is the definition of modular, sometimes multi-system units called interim products, and that the design and planning of these units is controlled largely on the basis of geographical regions in the ship called zones. Refer to Figure 4, production-oriented zones.
 - Zone outfitting, as contrasted with conventional outfitting by functional system, recognizes that certain multi system interim products, i .e. , significant sub-assemblies of outfit materials, can be produced more efficiently away from hull erection sites. This approach allows most of the outfitting work to be accomplished earlier and in shops where it is safer and more productive. Outfitting, thus organized, is not a successor function to hull construction, but is accomplished simultaneously with it, and hence is free as much as possible from dependence on hull construction progress.
 - Zone outfitting is divided into three basic stages listed by order of priority:
 1. On-Unit. The assembly of an interim product consisting of manufactured and purchased components not including any hull structure.
 2. On-Block. The installation of outfit components, which could include a unit, onto a hull structural assembly or block prior to its erection.
 3. On-Board. Installation of any remaining outfit material and the connection of units and/or outfitted blocks.
 - The pallet concept is the method used to organize information to support zone outfitting. Literally, a pallet is a portable platform upon which materials are stacked for storage and for transportation to a work site. In production a pallet also represents a definite increment of work with all located resources needed to produce a defined interim product; hence it is a work package. In design a pallet is also a definition of components of the various functional systems in a particular zone at a specific stage (time) of construction.

The pallet orientation is the most important concept to understand in the Japanese method of outfit planning. A pallet is characterized by a physical zone of the ship (accommodation, deck, machinery, etc. , see Figure 4), the stage of production (on-unit, on-block, or on-board), and even further into specific production areas, sometimes referred to as problem areas. Defining production/problem areas comes with experience and is the result of industrial engineering applied to justifying mass production concepts. A shipyard may decide to automate on-block production, for example, by using special handling equipment for pallets primarily defined by flat panel and different equipment for curved panel. Thus, a pallet would not only have a zone and stage, but on-block pallets would be designated as either flat or curved panel. At **IHI** a ship has between 1085 and 1973 outfitting Pallets depending on ship type.⁶ For the large ships (60,000 tons and over), typically over half of these pallets are accomplished on-unit or on-block as opposed to the on-board.

Perhaps the most significant aspect of the pallet concept is that planning for them occurs as a step in the engineering design instead of production planning. This allows systems designs to be translated into production requirements very early on in the shipbuilding process such that production, procurement, and design are all viewing the ship from the same production-oriented perspective. Since design must plan with production in mind, this facilitates the integration of design and production requirements which can improve productivity across several areas of the shipbuilding process.

Outfit planning is in a very real sense a form of group technology. Group technology is the process of classifying and coding parts based on their similarities into part families. Usually, there are two types. of similarities used either separately or in combination; these are by shape (round, square, etc.) and/or by manufacturing processes (drilling, tarring, milling, etc.). This has been applied primarily for the manufacturing and fabrication of parts. Some U.S. shipyards have already applied group technology to their pipe shop operations, for example, where similarities in fabrication are fairly straightforward. However, very little has been done to group assembly operations into families by similar processes in any industry. However, in a very definite sense outfit planning is a form of group technology that is directed at assembly work (even though it was probably not developed with that in mind). The ship is divided into pallets which consist of zone, stage, and

area with each pallet roughly representing the work of three people in one week. The work or labor content is roughly similar, for example, to one electrician, one welder, and one painter. Therefore, zone, stage, and area allow the shipyard to apply some mass production concepts, especially handling equipment, and similar work content allows the shipyard more control over production.

Outfit Planning has been defined and highlighted in context with the database design definition nature of this paper; however, to gain a more indepth understanding of the concept, four references are recommended. "A Decision Support System for the Outfit Planning Problem: Modeling and Conceptual Design" (Ref. 4) provides a very clear explanation of outfit planning in general. "Japanese Technology That Could Improve U.S. Shipbuilding Productivity" (Ref. 8) gives a quick, well-illustrated view of outfit planning in context with the other aspects of the shipyard. "Outfit Planning" (Ref. 25) and "Product Work Breakdown Structure" (Ref. 9) provide a very in-depth and detailed look at outfit planning for the dedicated reader. This order is preferable to facilitate understanding.

3.2 WHY OUTFIT PLANNING

Shipbuilding, though concerned with fabrication (especially on the procurement side), is primarily involved in the assembly and construction processes' necessary for ship erection. Management and control of such a large assembly operation is very complex, particularly because each ship is often a one-of-a-kind endeavor. Add to this the physical aspects of ship construction, large and inflexible material (e. g., steel plate, piping), outdoor construction, lack of standardization, limited work and storage space, etc. , and it soon becomes obvious that anything which can simplify the construction process will be very useful in increasing productivity. Viewed simply, outfit planning does this by breaking the ship down into a series of little units (other than the superstructure) or pallets instead of several large systems (piping, ventilation, etc.). These are much easier to control and actually increase the flexibility of management to meet deadlines, since many small, well-organized tasks are easier to change and/or reschedule than attempting to modify a few very large tasks.

The one-of-a-kind nature of shipbuilding is a significant barrier to productivity improvement since it reduces the ability of labor to learn through repetition (learning curve effect) and makes the application of mass processing/production concepts difficult to justify. In other words, shipbuilding is one of the few industries where there is very little learning curve effect from one ship to the next. Commercial buyers are not likely to order more than one ship at a time due to the large amount of capital that is tied up over such a long construction period (1-1/2 to 3 years), and even if more than one is ordered, each could be for entirely different purposes, hence different designs. Government procurement of a "series of ships" is also surprisingly nonconducive to the learning curve effect. Numerous changes during construction of a ship and from ship to ship essentially make each ship a different product.¹⁰

On the other side of the issue, there are many similar activities involved with shipbuilding almost regardless of the type of ship. If viewed from a systems perspective, there are many similar systems features from ship to ship, but it would soon be evident that there are too many complicated design and mission (purpose of the ship) differences to gain any large benefits from this perspective. And possibly, the biggest shortcoming of this system approach is its total lack of production considerations. Only totally standardized systems configurations would have any useful effect on production, which would be an unacceptable extreme.

Outfit planning, however, views each ship by zones which are common to most ships. From there, pallets are identified into series of similar work content combinations. These pallets will vary depending on the size and type of ship, but very often the work content and production considerations do not change very much. At worst, the total labor hours needed to complete a pallet would vary in proportion with ship size. This then allows workers, line management, and detailed design engineers the opportunity to focus on the similarities from ship to ship and, therefore, establishes a learning curve whereby each can become more proficient at their task(s). Just the reduction of job confusion alone could be very beneficial in the hectic management environment of the shipyard. Also, the manufacturing benefits (reduced preparation time, flow line systems, faster throughput, less inventory, standard process plans, etc.) and design benefits (quick retrieval of design information,

design standardization) associated with group technology are realized via building on the similarities from ship to ship.

Outfit planning not only enhances accuracy in design and production control but also improves procurement control and materials management. Materials usually represent 50%¹⁰ of the production cost of a ship, so improvements in procurement methods and inventory control have a very significant impact on the overall cost of a vessel. A great deal of control is gained in procurement and inventory management by the pallet orientation of detailed design. Production schedules can be expressed in terms of pallet beginning and completion dates, which in turn allows procurement to establish an organized schedule. The early translation of systems requirements into work packages allows procurement to know not only the total quantity of a part type required to take advantage of economic ordering quantities, but also enables negotiating a time-phase delivery schedule (based on the production schedule) which reduces inventory carrying costs. A side benefit is that vendors will respond better to an organized customer who does not put unreasonable time constraints on them. Procurement will also have more time to react for ordering long lead time materials as well as reducing the chance for ordering errors. The procurement process is viewed in Figure 8 on a pallet-by-pallet basis.

If the outfit planning method improves procurement methodology and inventory carrying costs by 30%, which is a justifiable assumption based on inventory alone, this would represent a 15% improvement (50% material costs times 30% improvement = 15% improvement) in the overall cost of building a ship.

Outfit Planning could easily represent one-third of total labor costs of ship construction. This projection is based on the estimate that outfitting, in the traditional use of the word, represents 50% of the total labor cost of building a complex naval vessel.⁴ This figure will be less for commercial ships; currently, there is no hard estimate, but it is assumed to be between 30 and 50% depending on the type of ship. However, this 50% figure for outfitting does not include pre-outfitting which, if added, would readily make the overall potential of outfit planning a minimum of 50% of the total labor costs for the construction of most ships. The U.S. Bureau of the Census reported that in 1977, at least 66% of the cost of a ship could be attributed to value added. Therefore, if the potential for outfit planning is 50% and

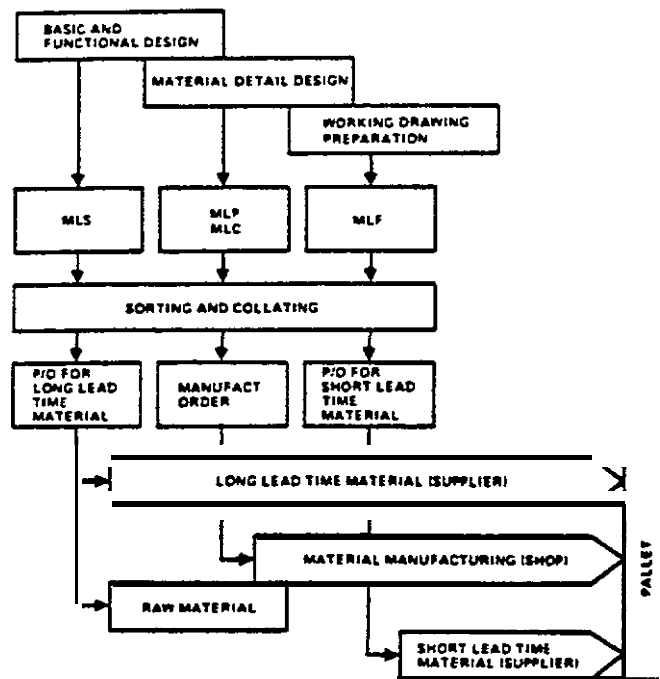


Figure 8. Relationships of material lists to design and to material procurement. ⁸ Accuracy and timing of the sorting and collating functions are critical. In addition, to sorting for long and short lead time and manufacturing-order materials, items identified in materials list for piping (MLP), materials list for components (MLC), and materials list for fittings (MLF) must be compared to those in materials list by ship functional systems (MLS). Also, the end product of each MLP and MLC must be accounted for in an MLF.

the total value added is 66%, the impact of outfit Planning is 33% or one-third of the total cost of the ship.

It is difficult to quantify in hard dollar figures exactly what the impact of implementing the Japanese outfit planning methods would have on a U.S. shipyard labor picture. However,⁸

"On-unit outfitting offers the greatest potential for improving overall shipbuilding productivity as compared to the other two outfit methods, i.e., on-block and on-board. Hence primary emphasis is placed on maximizing on-unit outfitting. The key advantages are:

- (1) Reduced construction time due to parallel construction of structure and outfit.
- (2) Minimal impact on hull construction schedules.
- (3) Increased outfit levels.
- (4) Reduced interface of outfitting and structural activities.
- (5) Improved sequencing and control of work. Earlier application of work.
- (6) Work is performed in shops which provide ideal working conditions and promote higher productivity.

IHI and Mitsui stated the following man-hour savings for on-unit and on-block outfitting:

On-unit versus on-board = 70% savings
On-block versus on-board = 30% savings. "6

If on-board is primarily how U.S. shipyards outfit currently, then very significant changes in person-hour savings may result. So if the outfit planning labor can improve by 30% (60% of outfitting is divided equally among on-unit and on-block instead of on-board resulting in $(70\%)(30\%) + (30\%)(30\%) = 30\%$ estimated savings and 40% is still done on-board representing no savings), then there is a 10% improvement in total shipbuilding costs (33% impact of outfit planning times 30% estimated savings = 10%).

The net effect of implementing the Japanese outfit planning methodology is only conjecture in lieu of any accurate figures. Procurement and material improvement is speculated to contribute 15% to overall cost improvement and labor savings to contribute possibly 10% due to outfit planning. No speculation can be reasonably quantified for the improvement in the quality of work, the learning curve effect, or the improved schedules and designs, but they are

also going to improve the overall cost picture of shipbuilding with the implementation of outfit planning. Outfit planning alone, therefore, may improve the overall cost structure of an American shipyard by 25% if the previous assumptions are correct. The ability to compete head-on with the Japanese, who can build a ship in half the time for half the cost, would still not be fully realized, but a U.S. shipbuilder would be well on the way. No one technique alone will fully achieve this productivity improvement goal, but a cost reduction of 25% would certainly be a significant step in this direction.

3.3 HOW OUTFIT PLANNING IS DONE

It is a misconception to believe that outfit Planning can be done separately from other planning activities such as hull construction. How to divide work into pallets or even whether to do so is highly dependent on the experience of a shipyard in outfit planning, the abilities of the design department to interpret production requirements, the way management sets milestone schedules, and the emphasis or approach of the shipyard to procurement and materials management. The Japanese have evolved into their current practice through rigorous application of industrial engineering and by recognizing a fourfold purpose in planning for ship construction which are:

1. Planning with emphasis on the assembly nature of shipbuilding.
2. Designing for production/productibility.
3. Recognizing the importance of procurement.
4. Focusing on the similarities from ship to ship.

Evolution is emphasized because outfit planning is as much a management philosophy as it is a technique to be applied and it certainly cannot simply be plugged-in overnight. Not even the Japanese would understand all the ramifications of such a fast change since their implementation of the ideas was done gradually over a long period of time. Certainly their experience in outfit planning is invaluable and makes them quite a worthwhile consultant, as some U.S. shipyards are finding out, but this is no substitute for patience, perseverance, and long-range strategic plans for effective implementation of the method.

The whole outfit planning approach could be referred to as the group technology of large assembly operations (refer to Section 2.2.7). Instead of

viewing a ship only as a compilation of systems inside a superstructure (shell or hull), they have chosen to view it as a collection of assemblies (pallets in units and blocks) which are put together inside a superstructure. In fact, very little part fabrication is done at a shipyard with the exception of steel plate cutting and pipe fabrication, and most direct labor is involved with joining and assembly work (welder, shipfitter, pipefitter, rigger, electrician, sheet metal worker, etc.). In fact, 48% of the total work force are directly involved in some form of assembly work, 36% in other production work, and 16% of the total work force are in non-production jobs (managers, administrators, and technical professionals).¹⁰ This means that almost 60% of the production work force are directly involved with assembly work which is a strong indication that improvements in assembly/construction methods will have the biggest labor-saving payback.

The United States and Japan pursue basic functional systems design in much the same way, but by the end of the detailed design phase, the Japanese have a zone/pallet detailed design whereas most U.S. shipyards are still carrying a heavy systems orientation (refer to Section 2.2.4). This may seem merely a matter of preference; however, it is actually a key difference contributing greatly to Japan's almost double productivity figures relative to the United States. Section 2, on Background, discusses the functional differences in the U.S. and Japanese approach and stresses the importance of transition design; however, a schedule comparison of milestones (Table 8) brings proper perspective on the issue.

The overlap of design, material procurement, and production is facilitated with a product-oriented detail design (delineating zones on drawings and listing materials that are to be assembled for each zone at a specific stage of construction)⁸ which contributes greatly to the downstream control of production and assembly and accounts for much of the improvements in the Japanese schedules.

This production-oriented, detailed design takes the systems and break them up into pallets or work packages which are the equivalent of 40 to 120 person-hours of labor involving two or more crafts which facilitates production control whereas a systems approach will end up (since work packages are not even considered in detailed design, process planning must have the added task of trying to determine work content) in work packages of 200 to

TABLE 8. TYPICAL CONSTRUCTION SCHEDULE FOR SELECTED MERCHANT SHIPS^{8, 10}

	Months Required for Various Ship Types				
	United States				Japan
	Dry	Ore Bulk			New design and standard-carao bulk container or RO/RO
Contract award to start of fabrication	6	8	5	9	6
Start of fabrication					2
Keel to Launch	9	7	7	11	3
Launch to delivery	6	5	5	6	3
Total	27	27	21	30	14

2000 man-hours usually. involving a single craft or trade.⁴ The average system-oriented work package involves a 3-month span time with about 500 person-hours, though 1000 to 2000 person-hours are not uncommon. Compared to the work packages for production-oriented designs which usually span a time period of 1 week,¹⁷ it should be apparent that "... the actual size of the work package is a reflection of the degree of control desired by shipyard management."¹⁷

The subjects of procurement and focusing on the similarities from ship to ship have already been thoroughly covered in a previous section (Section 2.2.5), but their importance should be emphasized. The ability to schedule around pallets gives procurement added control over delivery schedules and inventory levels which reduce costs. With purchased materials and services, a great deal of which is for fabricated components, representing 50% of the total cost of the ship improvements to this area can not be neglected. Again, it is the production-oriented detail design which allows a Japanese shipyard to relate different ships to each other based on their similarities. This facilitates the learning curve effect and justifies standardized process methods (including production concepts).

3.4 IMPLEMENTATION APPROACH

The most important thing an American shipyard can do if they are seriously considering implementing the Japanese outfit planning method is to develop a **5 to 10 year** (long-range) strategic plan. It would be disastrous to assume that a Japanese shipyard could come in and implement their system in a U.S. shipyard in 1 year and make it work as well as it does in Japan or even at all. This is not to say that a Japanese consulting firm cannot be of great assistance, because they can, as is evidenced at Avondale Shipyards.¹⁵ A shipyard should expect to assign a dedicated staff at three levels of planning simultaneously. These are the strategic, tactical, and implementation planning levels.

The strategic level planning should be comprised of a mix of company executives and upper level managers from production, design, and procurement. Their main function will be to devise a long-range, 5 to 10 year, strategic plan for the evolution of the shipyard based heavily on the input from the tactical and implementation groups only with a higher level perspective on the goals and objectives of the shipyard. This not only ensures the integrity of the overall plan, but exhibits the commitment and leadership vital to bring about progressive change in the company.

The tactical level of Planning might include some of the same people from the strategic group as a liaison or for expertise reasons, but this group will primarily focus on 1 to 3 year objectives of incorporating the outfit planning method. For this reason, possibly more operation-oriented personnel from production, design, and procurement should be utilized. It will be their task to look at the shorter range possibilities of outfit planning, identifying areas which could provide the most immediate returns on investment. This group should be encouraged to take a creative approach to improvement ideas and, therefore, not hesitate to deviate from the current thinking or techniques of outfit planning. The more they can rethink the shipbuilding process in the context of outfit planning and the specific facility, the more likely the shipyard will benefit from these improved concepts. The tactical group will be responsible to keep within the objectives of the overall strategic plan. The other role of the tactical group, however, is to provide sufficient information to the strategic planners to make long-range decisions, and with

this in mind it is always possible to modify the strategic plans in lieu of better improvements uncovered at the tactical level.

The implementation level, then, is where the actual concepts translate into action items. No one group would be in charge of implementation; rather, groups would be formed which are directly involved with a given proposed plan of action, preferably with other areas involved in an assisting capacity. Since this involves the actual "doing" of the work or turning plans into reality, some method of recording the actual (versus the planned) benefits should be used in order to provide the strategic and tactical levels with a way to evaluate their plans in context with actual performance.

It would be better if these planning groups were involved in more than just outfit planning concerns. The overall concepts of strategic, tactical, and implementation planning are not new, by any means, though they are not often visible, in a task force fashion or otherwise, to the overall shipyard which is necessary to demonstrate progressive leadership. Also, any one issue if looked at in isolation, even a management philosophy/method, is by definition not strategic. The whole productivity problem needs to be analyzed at all three levels without excluding any of the issues. If outfit planning improves productivity 25%, the U.S. shipyards still need another 25% improvement to be at an equal competitive position with the Japanese, so it is clear that one technique alone will not accomplish that goal.

4. HIGH LEVEL DATA BASE DESIGN MODEL

This section describes a high level data base design which supports outfit planning. It was crucial to gain a holistic understanding of the ship-building industry and then to define outfit planning in more detail before establishing the information requirements necessary for maximum control of outfit planning activities. The following sections are laid out especially to highlight the definition of data base management (Section 4.1) and a lay-person's explanation of what data bases are all about (Section 2). These are specifically formatted for those who are unfamiliar with data base management concepts; however, it is probably worth skimming even for those who are familiar. Section 4.3 then relates what steps are involved in developing a conceptual design of a data base management system. Finally, Sections 4.4 and 4.5 explain the actual high level data base model and the recommendations on how to use it, respectively.

4.1 DEFINITION

A data base is essentially a group of "storage bins" for information which reside in a computer. The data base design is highly dependent on what the company desires to use the information for. In other words, the way in which the storage bins are defined (data base design) makes it easy or difficult to locate or retrieve the pieces of information desired, depending on the way in which the information will be searched for. Carrying the storage bin analogy further, assume in a warehouse that storage bins have been defined for parts based on their shape. All round parts would be in one bin, all square ones in another, etc. Clearly, this would be a very useful design if parts were always searched for by what shape they were; however, if the part number were used to search for a part, it would be very difficult to find the proper storage bin for that part, and hence, shape would be a poor design concept. The same is true with information. Information can be categorized in many ways, but the task of designing a good data base is to try to arrange data depending on the way it is going to be used.

A more formal definition reads:

"A data base is a collection of operational data [information] used by the application systems of some particular enterprise. "

Application systems are essentially the software programs and report generators used by a company. Operational data is any relevant information having to do with running the business. In the model developed in this paper the application system(s) is outfit planning and the enterprise is a U.S. shipyard. It is important to think of operational data in terms of relationships or associations between certain basic entities.²⁶ An entity is anything about which there is a need to collect/record information on. To illustrate this for a part type, relevant information might be part number, part name, color, and weight; for an employer it could be social security number, name, and job description; for a project it could be the project number, customer name, and project description--part, person, and project, therefore, are all information entities. The aspects that describe the entities are called attributes. The next section will attempt to develop these concepts further.

4.2 LAYPERSON'S EXPLANATION OF DATA BASES

In this analogy a series of filing cabinets will be related to a computer data base. Conceptually, there is very little difference except for the physical storage medium (paper versus magnetic images on disks or tape) and ease of access (computers are faster than file clerks.". . . usually).

First, envision the information aspects of almost any report in a manufacturing company. It consists of bits and pieces of information from many areas of the facility. For a closer look at any one of them, consider a process plan for part fabrication, for example (Figure 9). Now envision several other reports and forms which also use some of the same information, but for different reasons, such as a vendor purchase order, a work ticket (Figure 10), an assembly schedule, a milestone plan, or pallet assembly process plan. The problem is how to effectively handle the multifaceted aspects of information control, storage, and communication.

This then relates to the responsibilities of a file clerk in that the file clerk must design a filing system to best store, access, and maintain information. However, this is not a normal file clerk. This file clerk does

Shop Order No. _____	Date _____
Part No. _____	
Quantity _____	
Planned Operations:	
(10) _____	
(20) _____	
30) _____	
40) _____	
etc.	

Figure 9. Process plan for part fabrication. This contains shop order and part numbers, the quantity to be produced, and a series of planned operation steps.

Work Ticket No. _____		Date _____	
Shop Order No. _____			
Operation Sequence No. _____			
Setup	Fabrication	Teardown	Quantity
Time Start:	Start _____	Time Start:	
--	Stop _____		Good: _____
Time Stop:	Start _____	Time Stop:	Reject: _____
--	Stop _____		
--	Start _____		Rework: _____
	Stop _____		

Figure 10. Sample of a work ticket for a fabrication process. This has the stop order and operation sequence numbers in common with the process plan, yet this is for work tracking.

not have to locate a specific report, the file clerk just needs to be able to locate the information for a report and it will automatically be put into the report format (this assumption simply frees the physical limitations of the file clerk, to make this analogy go smoother). Ideally then, with this assumption in place the file clerk has certain objectives that would make the job easier. These are: ²⁷

1. information independence - making the information in the filing cabinets independent of the various reports needed (this is because of the assumption that once the information is located, there is no effort required to generate the report).
2. Information nonredundancy - minimizing the number of different files (filing cabinets, storage bins, etc.) which contain the same information.
3. Information relatability - having information in a form that all reports and forms can use or modify easily.
4. Information integrity - improving information quality, consistency, and recoverability.
5. Information accessibility - providing low cost, easy access to information stored in various filing cabinets.
6. Information shareability - insuring that many secretaries can access the same files without degrading performance (more easily understood with computers, but if there is only one main filing system for the whole company this would be a factor).
7. Information security - helping people mind their own business by keeping privileged information away from unprivileged people.
8. Information performance - providing proper controls for changing the filing system as time and changing user needs cause the basic systems requirements to change.
9. Information administration - supplying appropriate standards, procedures, and guidelines to ensure consistent evolution of the filing system as demands and technologies change.

Remember that this is not an expanded role for the file clerk for the sake of analogy. The file clerk would certainly have these important responsibilities if there were only one filing system for the whole company.

Now that the end result is understood and the reports, forms, and the responsibilities of the file clerk are established, it is time to examine how the file clerk lives up to these responsibilities. Upon examining the requirements, the file clerk needs to set up the filing system such that it can access information independently of reports and forms (requirement 1). To do this, each file cabinet drawer contains information on one entity of information, Figure 11, and each file (entity class member) always has a unique identifying attributer(s) as well as several descriptive attributes which further define the file (entity), Figure 12. For examples shown in Figures 11 and 12, the filing cabinet is one of many which make up the whole system, but each drawer here contains a unique information category (entity). These categories are pallet, pallet-part cross-reference, and part information. Looking at the pallet drawer, there are several separate files each describing an individual pallet. Each pallet file (Figure 13) can be identified by a pallet number because it is unique to each separate occurrence of a pallet. There will be a set of descriptive characteristics that will define each pallet and all pallets will be described by these same types of information (size, shape, etc.). Notice that not only is there now a system that is independent of reports and forms, but there will be only one place in the filing cabinets where one can find an important piece of information (requirement 2, information nonredundancy). In other words, there is nowhere else in the filing system where pallet information can be found. This saves an immense amount of time if changes are required. For example, if pallet 1 needed to be painted a different color than it is currently described as needing, then all the file clerk has to do is locate that one file and change the color information. If the file clerk had set up the traditional filing system based on report types, the clerk would have to find every report that had pallet 1 mentioned on it and change the color. So, with this independent filing system the information integrity has increased dramatically (requirement 4).

To develop an understanding of the relationships each file drawer has with another, it will be useful to carry this example just a bit further by defining the relationships possible between the files (members) of the three file drawers. In Figure 14, a specific file, pallet 1, is identified and we want to know which part types are included in this pallet. For this the cross-reference files are used, and they identify three parts for this example. Notice also that the reverse could occur. Which and how many pallets a specific

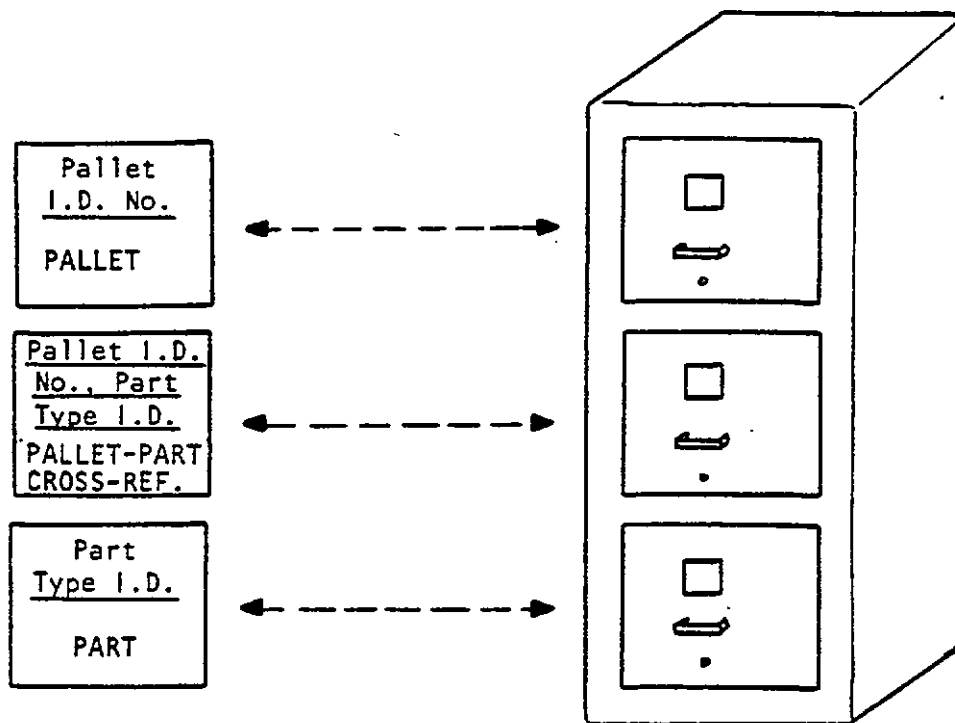


Figure 11. Filing cabinet analogy. Each filing cabinet drawer contains information on one entity class category. In this case, pallet and part information each have a drawer as well as a cross-reference entity which relates which part types to to which pallet and which pallets require various part types.

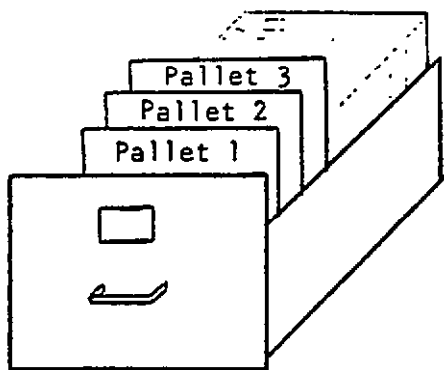


Figure 12. Individual file drawer. A filing cabinet drawer contains several files relating to separate or distinct occurrences of an entity (or entity class).

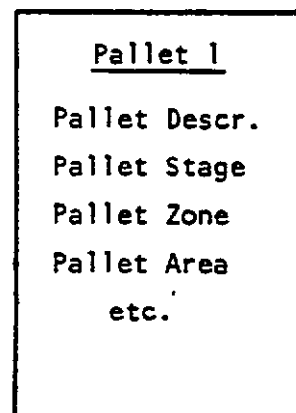


Figure 13. Individual file. Each file can be identified by a unique attribute called an identifying attribute, and is described in more detail by other bits and pieces of information called simply attributes.

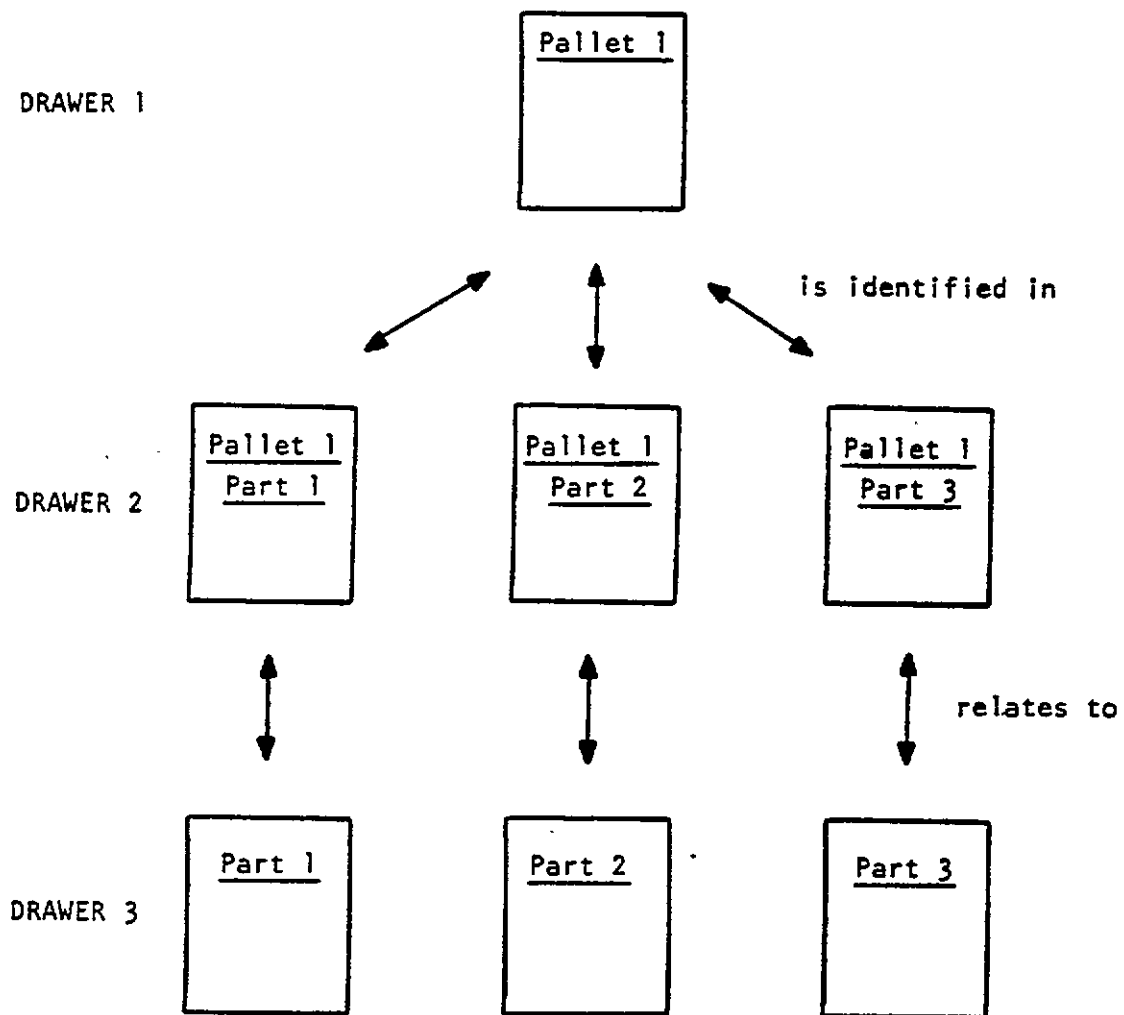


Figure 14. File relationships. Pallet 1 is identified in three cross-reference files which relate it to three part files (one for each that was cross-referenced).

part type is included on could be determined by simply looking in the cross-reference file for all part 3 occurrences, for instance. It is easy to see that part and pallet have unique identifiers, but it is less obvious that file 2, the cross reference drawer, is unique. The reason is that each pair of identifiers (pallet identification number and part number) will have only one occurrence and is, therefore, unique. Without the pallet-part cross reference file a very important relationship is missing--that is, the ability to match parts to pallets. It makes very little useful sense to acknowledge that a pallet can have many parts and a part can be included in many pallets without specifying which parts go to which pallets. The notation that is used to express the relationship is explained in Figure 15. This is the short hand way to graphically represent the previous Figures 11 and 14 (and the reverse case), and is the method used to design a file management system of this nature.

To understand data base design, simply re-read this section substituting the words file clerk with data base administrator, file cabinets with data base, file drawer with entity class, and file with entity class member; and attributes stay the same. (The job descriptions and concepts involved for file clerks, data base administrators, and data base design personnel have been necessarily oversimplified for the sake of clarity.) Figure 16 below relates this analogy. Notice that to fulfill the overall requirements of information performance and information administration (requirements 8 and 9) the graphical model could be very useful. It provides the data base design structure and can be used in plan or design changes in the current system. This will be demonstrated later as the specific outfit planning model is discussed.

4.3 DEVELOPMENT OF A CONCEPTUAL DATA BASE DESIGN

The overall design development cycle, Figure 17, provides a logical sequence in information gathering and organization in order to produce quality results effectively and efficiently. Since conceptual or high level design is the cornerstone of an overall detailed design, it is important to use techniques which can be used at a high level as well as a very detailed level. Conceptual modeling techniques have gained wide acceptance in the last 10 years for these purposes, and many modeling methods have evolved. The con-

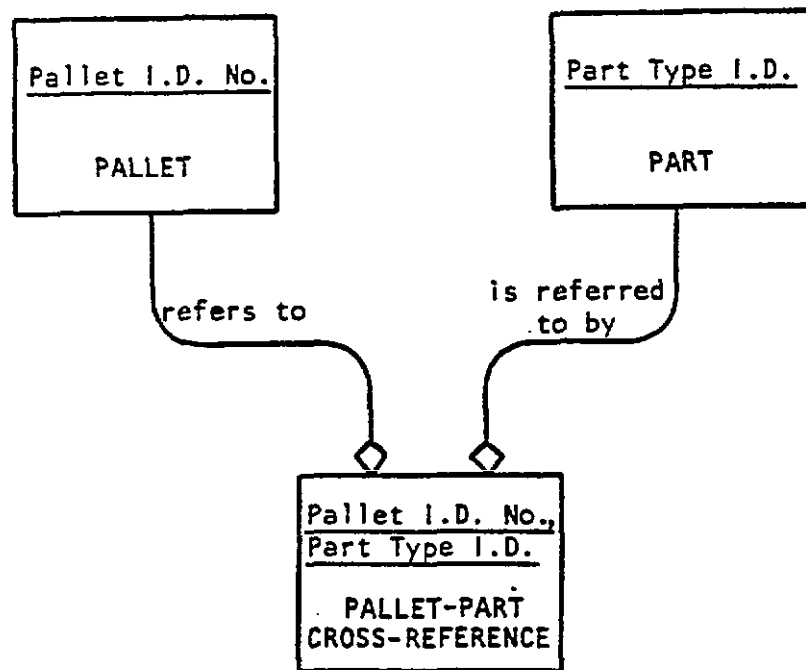
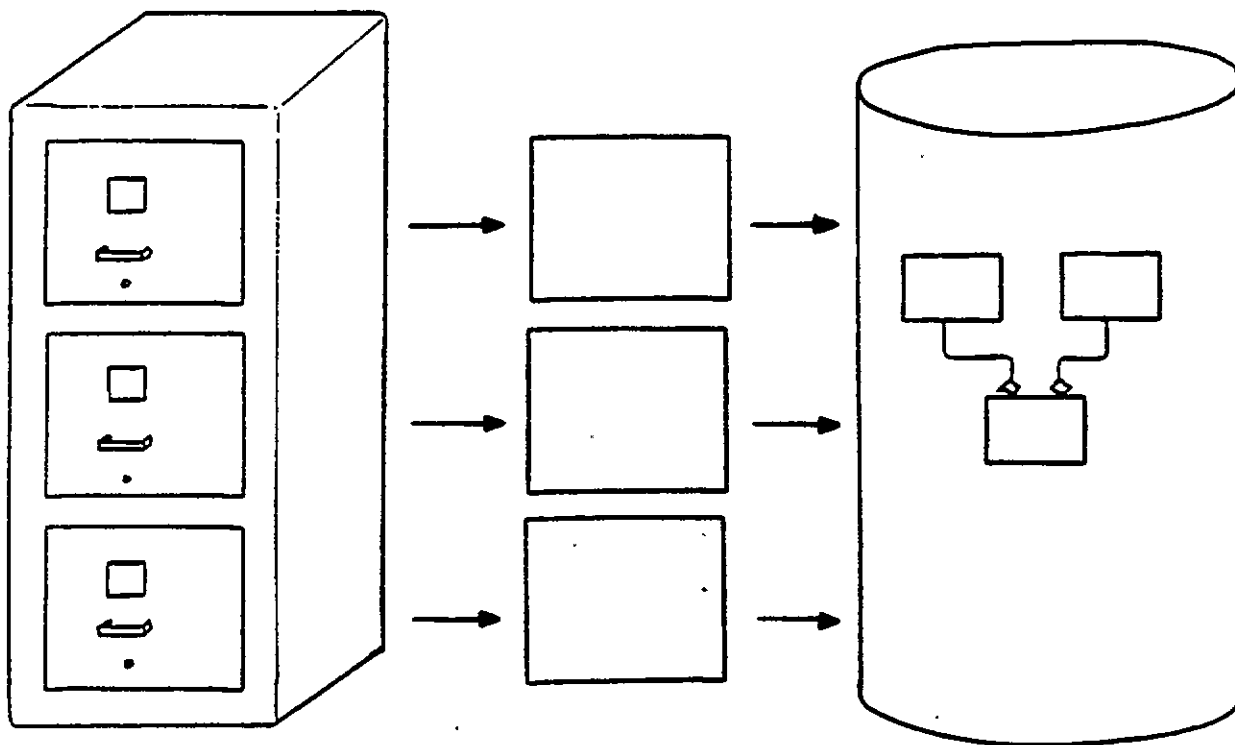


Figure 15. Entity class relationships. An entity class called pallet is uniquely described by the identifying attribute pallet I.D. No. and refers to zero, one, or many entities called pallet-part cross-reference, which is uniquely described by both pallet I.D. No. and part type I.D. and correlates directly to the one occurrence of part type identified in the cross-reference. Each entity part can be referred to zero, one, or many times by a pallet-part cross-reference.



FILE CABINET

ENTITY CLASSES

COMPUTER DISK

Figure 16. Relationship of items used in the analogy (Section 4.2).

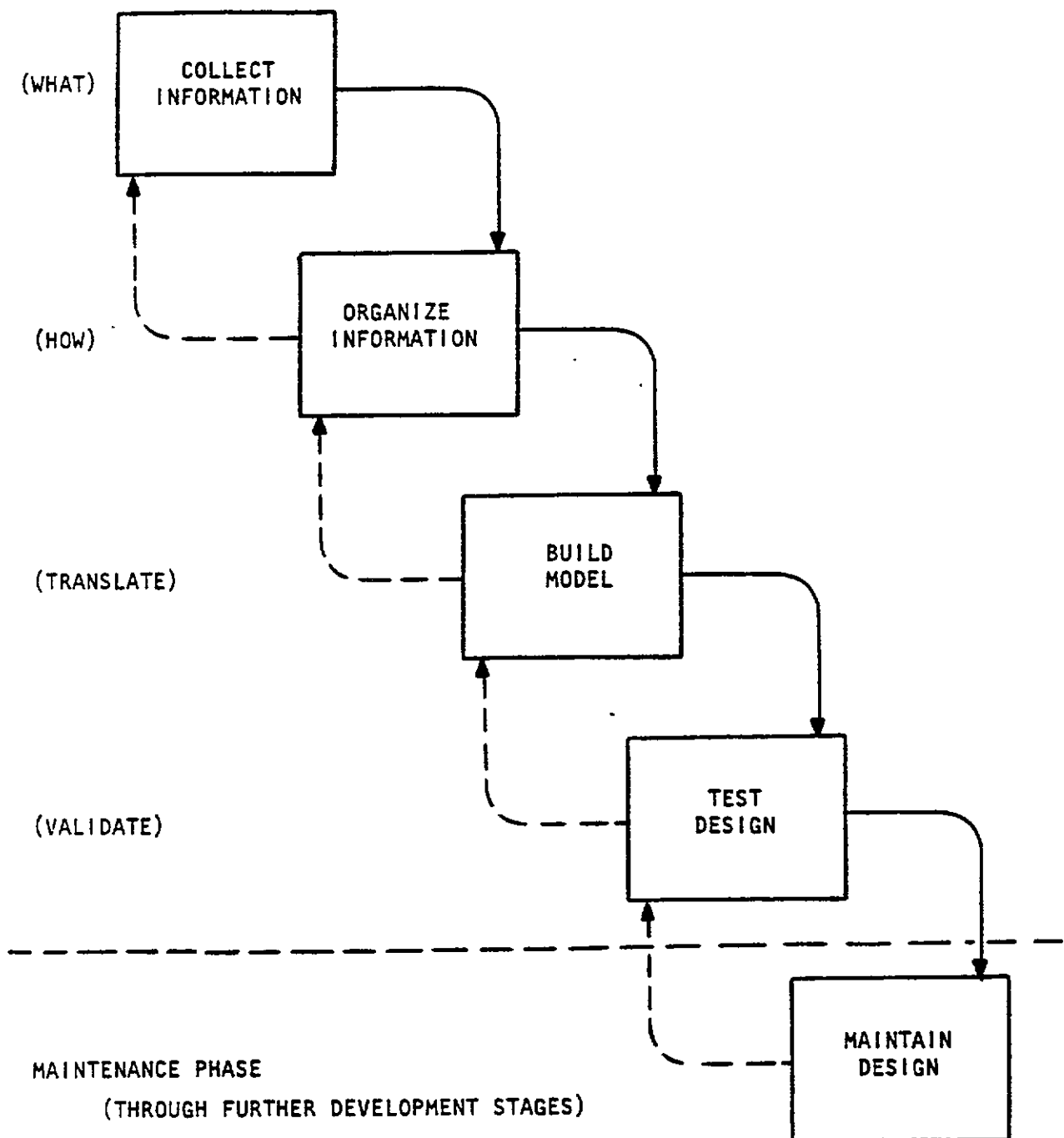


Figure 17. Design development cycle.²⁸

ceptual modeling technique used in this project²⁹ is elaborated on in this section as the design steps in Figure 17 are discussed.

The first step is information collection. Information collection techniques are fairly standard in most conceptual modeling methods. Information is usually gathered by a variety of methods including literature searches, surveys, interviews, comparison to similar systems, etc. , and the methods are usually used in combination, as was done for outfit planning in this project.

The next step is information organization. Organizing information properly is a crucial process in the development of a conceptual design and it is important that the graphic technique used can adequately group information into useful categories. The whole idea behind graphic conceptual modeling is to enhance creativity and clarity by going beyond the semantic problems normally associated with written textual descriptions. In fact, creativity is enhanced because graphic modeling techniques are being used as an organization tool and system (data base) definition is more accurate because the analysis can focus on the pieces before, after, or while they are brought together into a whole system concept.

Using thorough information organization techniques such as textual analysis methods and targeted graphic modeling, the next phase involves actually interpreting this information to create the high level conceptual data base design. It consists of bringing the individual pieces together to develop a whole system structure. The holistic configuration of the data base will be more than the sum of its parts due to the multifaceted nature of information relationships. This is why in actual practice a designer may start by trying to describe the whole system first, then develop individual parts of the model in more detail, and finally return to the whole system model and expand it further. It is certainly an iterative process which the conceptual modeling techniques greatly enhances. Without the clarity of such models, development would be quickly bogged down in long textual discussions, making modification difficult and possibly hiding foggy reasoning.

Extensive model testing is important to reduce problems later, in the implementation phases of the data base design. A model must be practical in the sense that it does not make incorrect assumptions (i.e., relating things that do not actually exist) or incorporate untested ideas. At the same time, it must be flexible so that it is not restricted only to the current operating

structures or technologies. This holistic systems analysis should favor a thorough systems definition, but expert review and direction are necessary to assure a non-bias, conceptual model. Actual test cases can be used as a sort of simulation or walk-through of the model. This tests the system logic and predicts actual usage characteristics.

The high level conceptual information model developed in this project provides a framework from which a more detail design can be developed. It is a high level blueprint of the intended product. Like a blueprint, however, as the actual product is being designed in detail, improvements and/or compromises must be made and these changes, modifications, and/or additions must be added back into original blueprints in order to accurately represent the "physical" product. If the product is only a component of a whole assembly, such as the outfit planning function is to the whole shipbuilding data base definition, then the design may need to be even more flexible to change since the other components' design will have some effect on it. Proper maintenance methods are not well defined at this point, however, and this will be an area of concern if an actual outfit planning data base is implemented.

The same design steps and modeling methodology as described here for high level conceptual modeling can be used to create a much more detailed data base definition. The graphic nature of the model allows expert reviewers to quickly and accurately understand the design and will also provide the basis for the further expansion of the model.

4.4 THE HIGH LEVEL DATA BASE DESIGN MODEL FOR OUTFIT PLANNING

The data base design model developed in this section of the report is a high level conceptual view of the informational requirements necessary to support outfit planning in a shipyard. It is a framework from which an in-depth, detail data base design could be developed. The modeling technique used²⁹ does not require in-depth training for a reader or reviewer to understand even though the development of an information model is quite involved. This ability to communicate clearly and concisely with the expert and non-expert in data base design/management is one of the greatest strengths in a modeling technique. There are only a few important modeling considerations to keep in mind, and they soon become reflexive, so that the reader/reviewer can focus mainly on the content and accuracy of the information relationships

established. The figures have been laid out with a narrative to facilitate the basic diagram reading and the textual description highlights the important information relationships and outfit planning concepts.

A brief description of the modeling symbolism is also useful to facilitate a more in-depth understanding of how to read them. First, Figure 18 presents the basic entity class symbol. As defined previously, an entity class is an information category which contains several individual occurrences or members (or filing cabinet drawers full of files). Each member of the entity class can be identified by one or more attribute classes called identifying attributes. (For any further clarification, refer back to Section 4.2 and study the filing cabinet analogy, or look ahead to Figure 20 and read the figure narrative.)

The only other symbol used in this modeling technique is the relationship lines which connect the boxes (entity classes). Figure 19, explains how these are to be read. In all the specific model breakouts (Figures 20 through 27) all the relationship labels are to be read from the top of the page downward. They can be read in the other direction only by interpreting the relationship label using the proper "reverse logic" also explained in Figure 19.

The best way to understand the overall model is to look at categories of information or logical groups of entity classes. Information needed to support outfit planning has been divided into seven groups of entities by the topical areas of contractual , systems and structural planning, outfit planning, process planning, part fabrication, monitoring, and procurement information. In the next several subsections each area is analyzed focusing on its contribution to outfit planning. Finally, the whole model is presented to show how each area contributes to the overall data base design. (It may be useful to some readers to scan in advance the holistic data base model given later, Figure 28, then return to the detailed category descriptions here. Note also that the Appendix contains a glossary of the entity classes used in the model.)

4.4.1 Contractual Information (Figure 20)

Contractual information directly affects the way in which the shipyard can do business and, therefore, affects outfit planning. A sales contract is awarded which specifies several contractual requirements which the shipyard

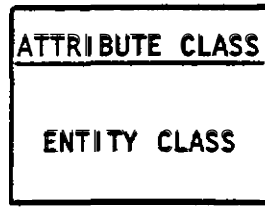


Figure 18. Entity class symbol for data base design.
Each entity class represents a set of members which can be uniquely identified based on an identifying attribute class.

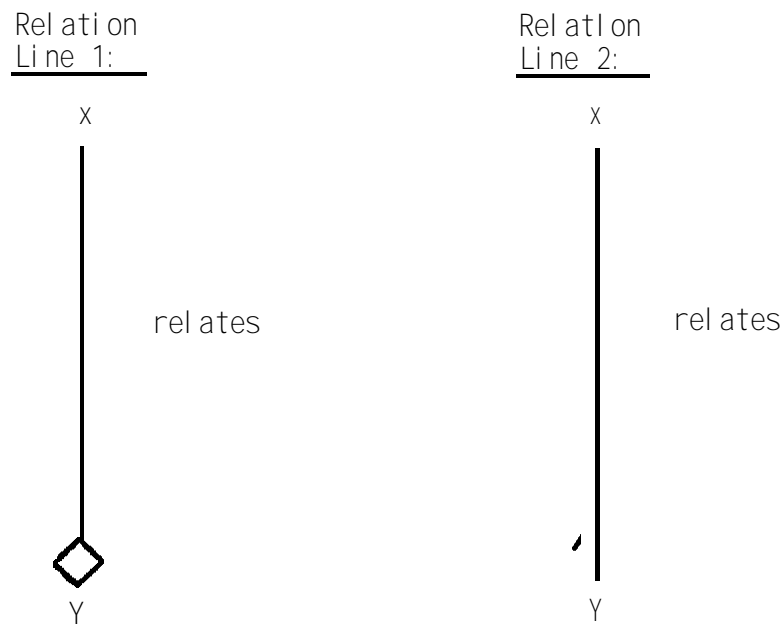


Figure 19. Relationship lines for data base design.
For the first line, top to bottom: X relates to zero, one, or many of Y; and bottom to top: for each member of Y it relates to exactly one member of X. For the second line, top to bottom: X relates to zero or one Y; and from bottom to top: each Y relates to exactly one X.

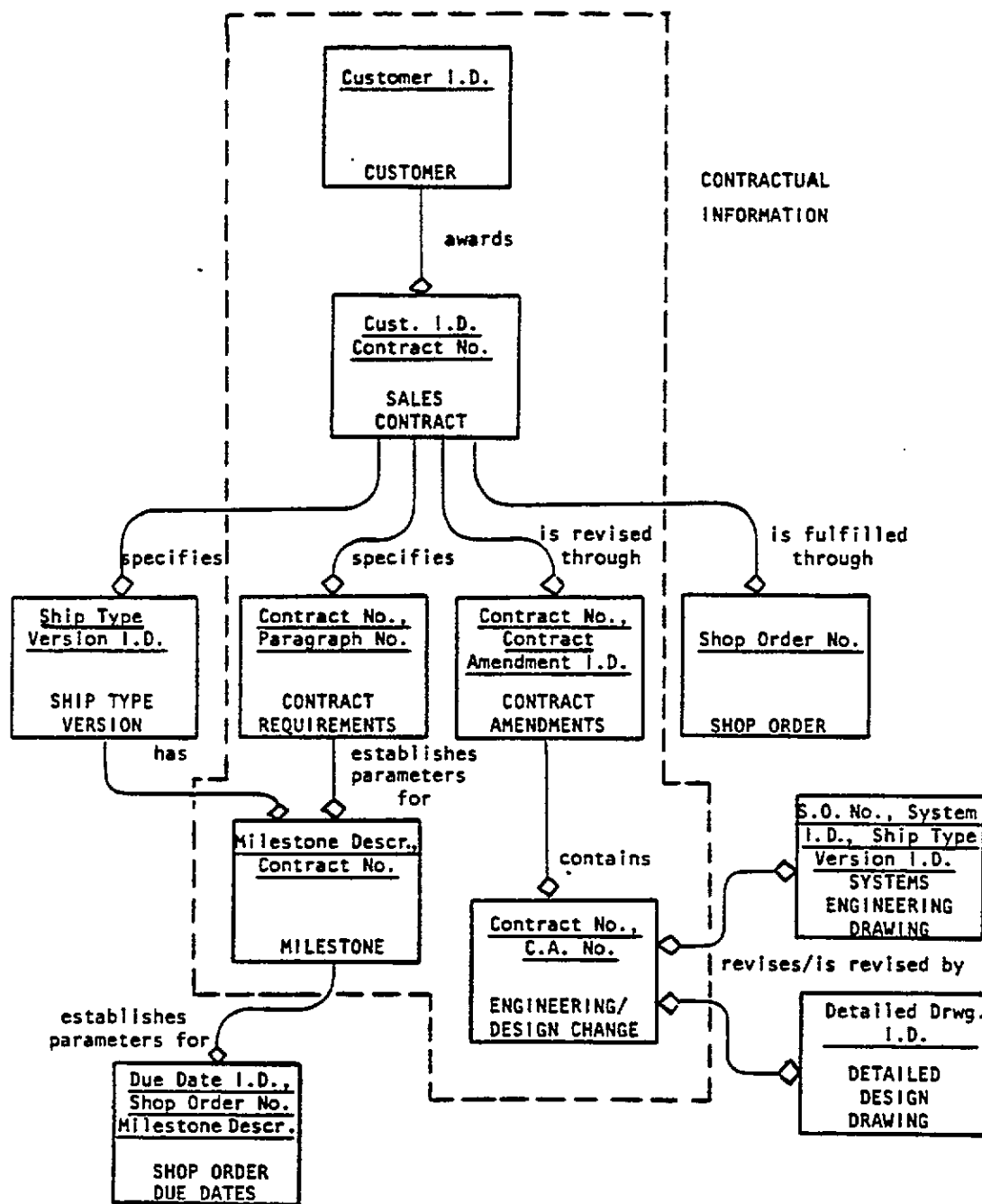


Figure 20. Contractual information needed to support outfit planning. A customer awards 0, 1, or many sales contracts. Each sales contract specifies 0, 1, or many ship-type versions and contract requirements. A sales contract is revised through 0, 1, or many contract amendments and is fulfilled through many fabrication and assembly shop orders. A contract requirement establishes parameters for 0, 1, or many milestones which, in turn, establish parameters for many shop order due dates. A contract amendment contains 0, 1, or many engineering/design changes. A systems engineering and detailed design drawing is revised by 0, 1, or many of these engineering/design changes.

must fulfill to satisfy the customer. These could include quality assurance, inspection, engineering and performance requirements, etc. If a detailed information model were to be developed, each type of contract requirement might constitute its own separate entity class; however, in this high level view it is simply important to realize that they exist and can be identified. The most significant contractual requirements relating to outfit planning scheduling are those that either explicitly or implicitly determine or suggest milestones for ship construction. The sales contract is also the legal document that allows the shipyard to establish an accounting vehicle by which to charge time and cost against the client. In this model a sales contract is fulfilled through several shop orders. A shop order is the internal work authorization for a work package which allows production to charge against the project. The assumption here is that there is one shop order for every work package. In a detailed representation of an information model this relationship would have to be examined more closely. If the shop order represents the work authorization for a work package, it is important to realize that the shop order due dates must be established as a function of scheduling. This is done by using the various milestones for a given contract to establish logical shop order due dates. In other words, each milestone will establish parameters for several shop order due dates.

As with any sales contract, there are usually several contract amendments negotiated between the shipyard and the customer while a ship is being built. Presently, it is quite a clerical achievement to keep track of all the revisions; however, with a computer data base that is structured to be information independent (Section 4.2), updates need only be made in one place. The contract amendments that are of considerable importance to outfit planning are

- A "milestone schedule" is not an entity class of its own because it is already implied indirectly by the fact that a milestone is traceable to a specific sales contract and more specifically, to each ship type version. A milestone schedule is simply the collection of all the individual milestones for a given contract and ship so it would not provide any information not already identified in the model. This is a good indication that "milestone schedule" is a physical report requirement and not an information entity class per se.

those that contain one or several engineering and/or design changes. A systems engineering drawing and a detailed design drawing could need revision as the result of one or many engineering design changes. However, the reverse is also true: for a given engineering design change, it "could affect one or several systems engineering (and/or detailed design) drawings. This redundancy was left in the model deliberately to illustrate (1) what the double diamond on the relation line means, and (2) how to tell when more information is required to make the model meaningful.

A cross-reference entity Serves to relate two information entities together in a more meaningful way than the "many to many" relationship which exists between engineering design change and systems engineering drawing as well as detailed design drawing. Thus, in this case a cross-reference is needed to resolve this relationship in a more detailed model to clear up these relationships, and Figure 21 would be one solution of the information relationships. For a more in-depth understanding of the cross-reference relationships it would be useful to review pallet-part cross-reference described in detail in the filing cabinet example in Section 4.2. In a high level conceptual view these cross-reference entities could be left out, but for the sake of a more thorough design they have been included where needed in the rest of the data base design model.

4.4.2 Systems and Structural Planning (Figure 22)-

Outfit Planning requires systems engineering design in order to "transition" to a pallet-oriented detailed design. In the normal course of ship engineering design a given ship type version is divided up into several systems. Each system is then described in detail by many systems engineering drawings. This is true in both the United States and Japan. At some point in the systems engineering design, however, the Japanese begin to break the systems down into zones, so for any system it can be cross-referenced into its respective zones. This breakdown becomes official as the Japanese then take systems engineering drawings and reference them to produce detailed design drawings.

4.4.3 Outfit Planning Information (Figure 23)-

The most important aspect of this high level data base design model is the specific outfit planning information. All other categories are necessary to support outfit planning, but this category describes the information which

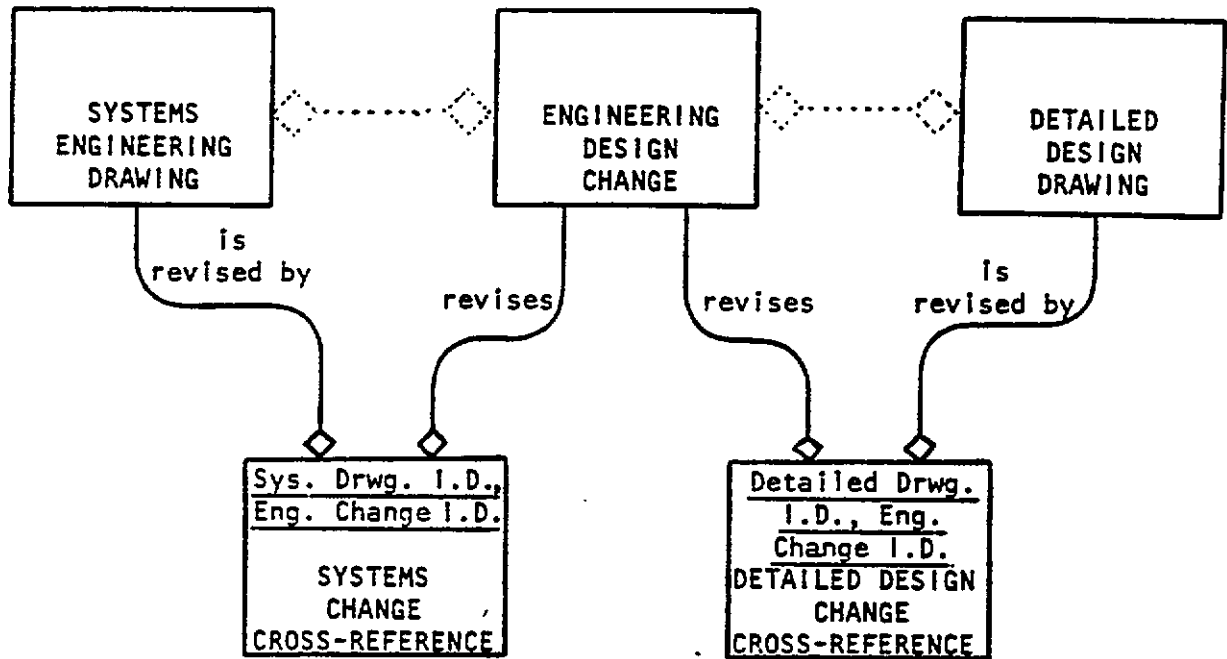


Figure 21. Resolving redundancies. In this case each instance of a drawing revision could be cross-referenced back to the engineering design change that caused the modification. Note that the identifying attributes on the cross-reference box will be unique. This then eliminates the double diamond or many-to-many relationship that existed before.

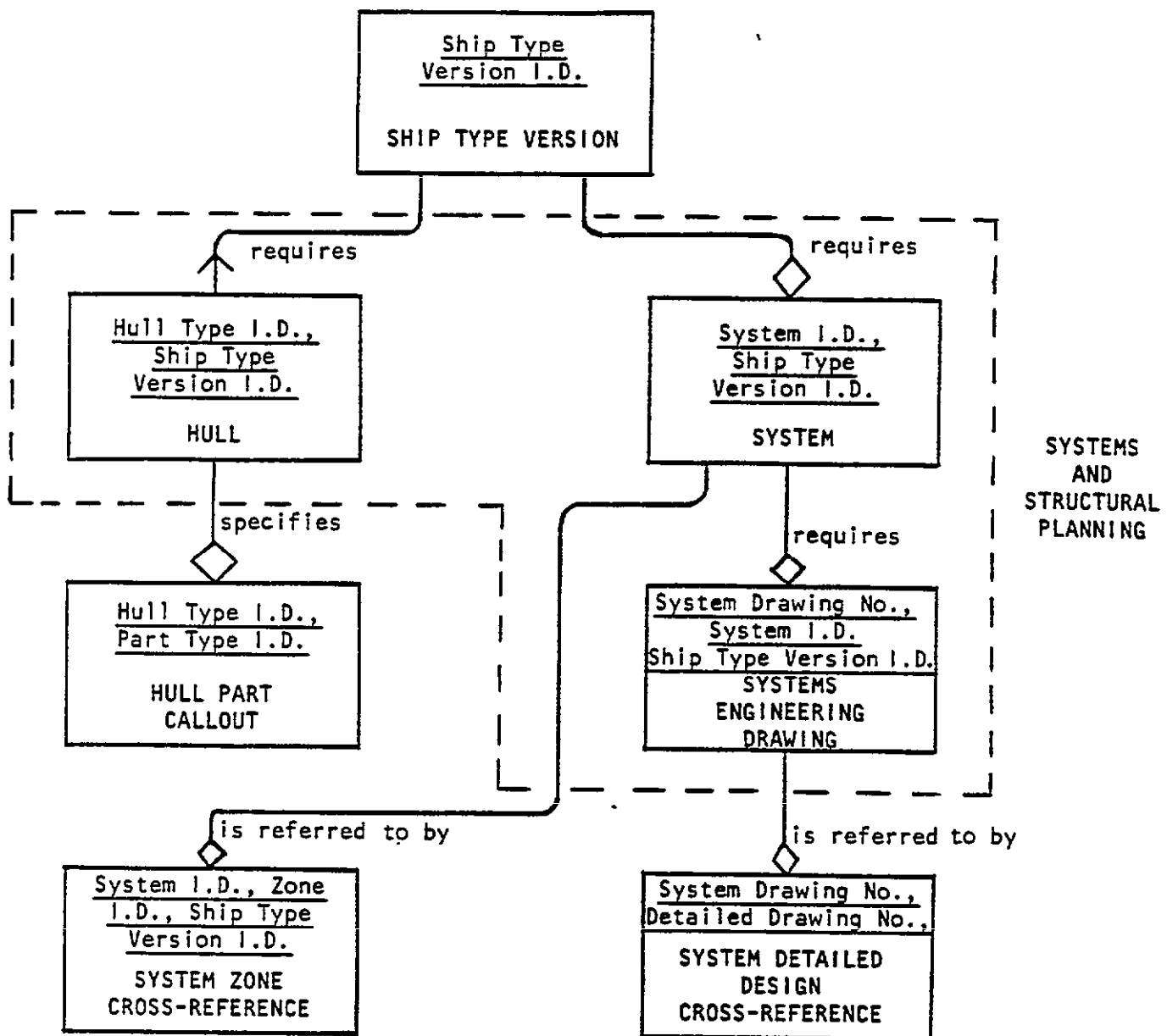


Figure 22. Systems and structural information necessary to support outfit planning. A ship type version requires zero or one hull type and requires zero, one, or many systems. A system (i.e., piping, electrical) requires zero, one, or many systems engineering drawings to describe it. For transition design the systems engineering drawings are referred to by zero, one, or many system-zone and system-detailed design cross-references.

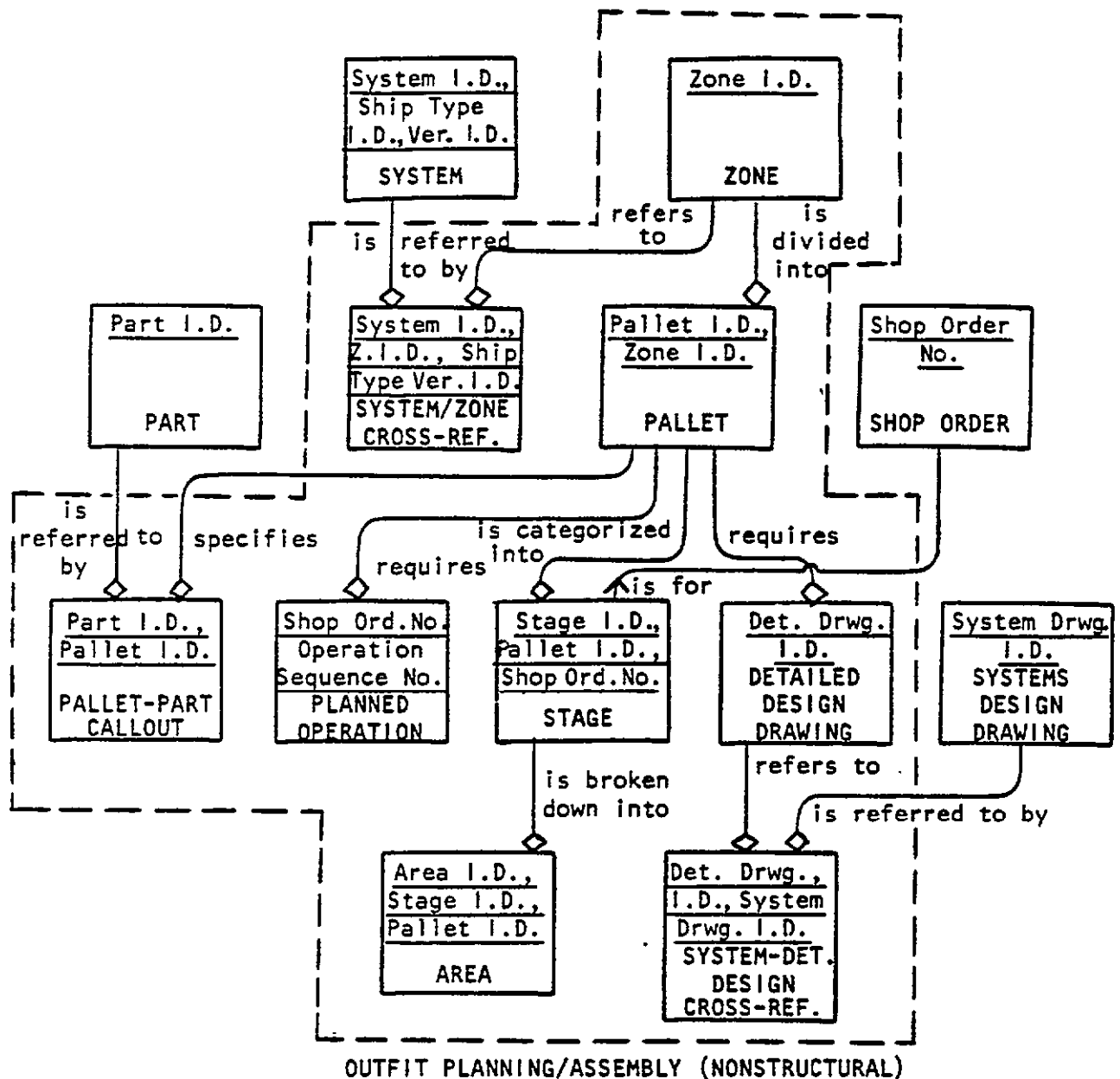


Figure 23. Outfit planning/assembly information. A zone is divided into zero, one, or many pallets, and a zone can refer to zero, one, or many system-zone cross-references (in other words, a zone has several systems running through it). A pallet is categorized into zero, one, or many stages which, in turn, are broken down into area categories. A pallet also requires zero, one, or many detailed design drawings (which refer to systems drawings). A pallet requires zero, one, or many planned operations for assembly and specifies zero, one, or many parts of which it is comprised.

is central to outfit planning itself. The key entity class is the pallet because it is the formation of the pallet in the design phase which allows procurement, scheduling, materials management, and even design more control over the actual production of a ship. A pallet is related to systems design through a detailed design drawing which can be directly cross-referenced to specific systems engineering drawings. The actual process of going from systems engineering drawings to detailed pallet-oriented design drawings is what the United States has been calling the transition design of outfit planning though there is no real term for it in Japan.⁵ This transition design, however, is the single most important process in outfit planning (or any true production-oriented design in any manufacturing concern). Another way to view the pallet, however, is by its physical location on the ship. Each zone has several pallets associated with it and each zone can be cross-referenced to major systems which run through it, so indirectly this provides another way to associate zones, systems, and pallets.

Other aspects which further describe or categorize a pallet are the stage and area. The stages are simply the on-unit, on-block, or on-board distinction of how a pallet is processed. A pallet can actually pass through all three stages of production, if necessary, or lose its identity later as, for example, a unit becomes a small part of a block assembly pallet and so on. For any given stage of production (on-unit, on-block, or on-board) the Japanese have tried to define logical categories of processing to help them justify mass processing techniques and/or flexible tooling, jigs, and fixtures; these are often referred to as production areas or problem areas and are simply referred to as "areas" in this model. Notice that a shop order is related to a stage of production and to a set of planned operations. This confirms that a "work package" is really a process plan for a specific pallet at a specific stage of production; an important relationship which a data base design should definitely establish. By the time a pallet has been classified in zone, stage, and area, its process plan is almost established. Combine it with the detailed design drawing and, to an experienced worker, the production instructions are practically all defined; in fact, these are sometimes the only "process plans" given to experienced Japanese workers (refer to the plan-do-see method in Section 2.2.7). However, it is still true to say that a pallet requires several planned operations whether implied, communicated verbally, or on a formal process planning form and the latter is recommended especially for providing instructions to inexperienced workers.

4.4.4 Process Planning Information (Figure 24)

The main role of outfit Planning is to provide a more efficient and effective method of production and, therefore, needs the support of process Planning information. There are two types of process Plans, one for part fabrication and the other for assembly of a pallet. The combination of a shop order and a part requires several planned operations which constitute a part fabrication process plan, and it is the combination of a shop order, a pallet, and the stage of production (not shown in this view) which compose a pallet assembly process plan.

Regardless of the type of process Plan, however, each planned operation requires the same type of information to support it. A planned operation calls out the use of materials, special tooling, and/or equipment in order to produce the product. Standard tooling is considered as a part of the planned operation description, but could easily be broken down separately, if desired, in a more detailed data base design model. For a pallet, a process plan could call out parts in the same way as materials are called out; however, it is the interpretation of this model that it is really the pallet itself (see Figure 25) which calls out the part and not the planned operation. This is a subtle distinction, and the user would never know which way the callout occurred because the process plan report or form (i. e., physical piece of paper) would contain the same information on it, regardless. •

4.4.5 Part Fabrication Information (Figure 25)

Outfit planning emphasizes the assembly nature of the shipbuilding industry. Part fabrication information, however, is required to support the assembly operations. When shop order (or work package) due dates are established

* The reason for the distinction comes about because a pallet will have a bill of materials (list of parts) associated with it regardless of whether the process plan has been defined, but if the data base set up such that pallet-part callout "belonged" to the planned operation, a pallet-part cross-reference is not established until the planned operation is defined. A simpler way to look at it is to realize that pallet-part callout is identified by attribute classes. Neither pallet identification nor part identification, as an attribute, uniquely identifies a planned operation; thus, the callout would not work if it belonged to planned operation.

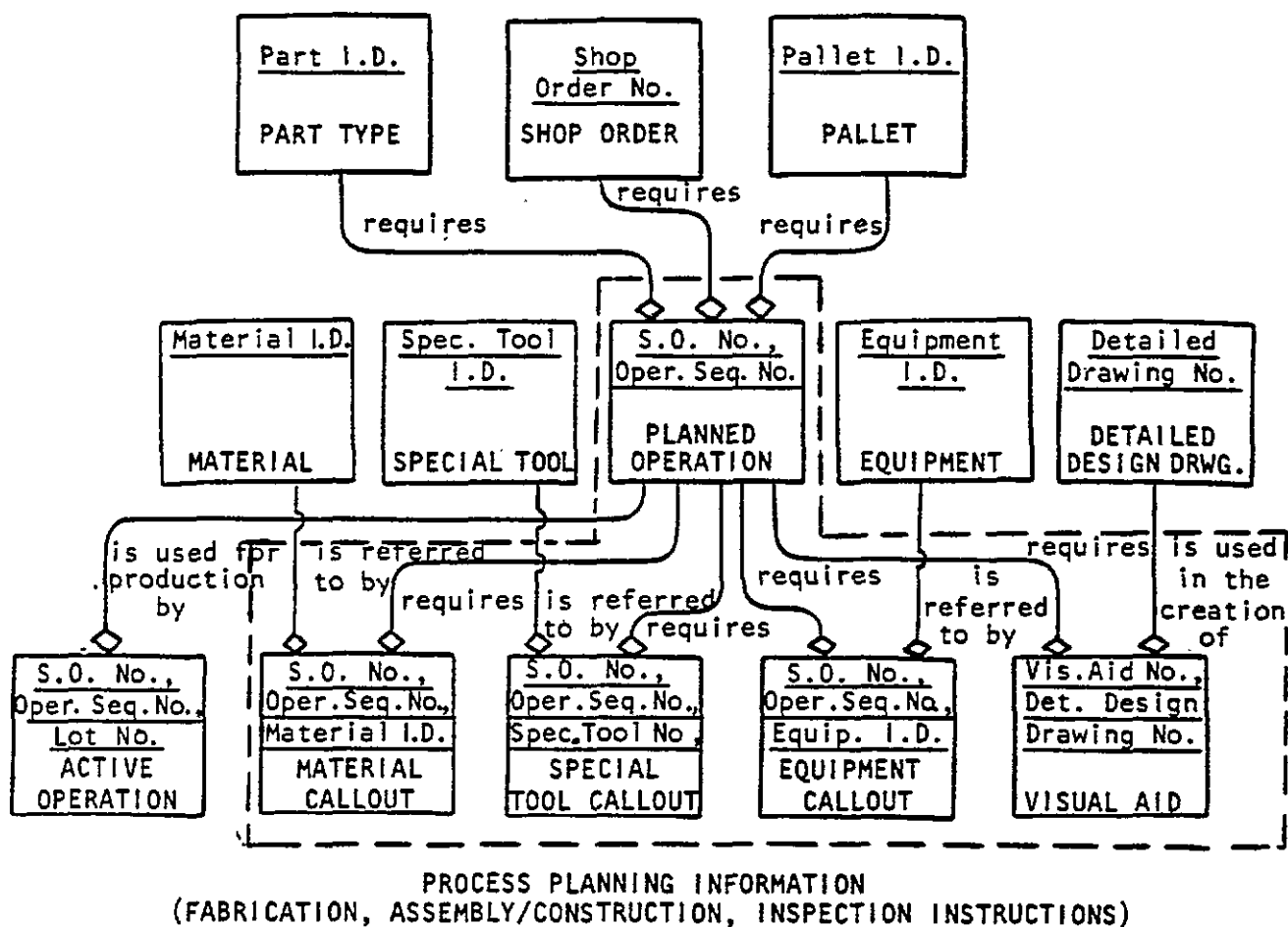


Figure 24. Process planning information necessary to support outfit planning. There are two types of process plans, fabrication of a part and assembly of a pallet, each requiring the same type of process planning information. A shop order is either for part fabrication or pallet assembly (outfitting) and requires therefore zero, one, or many planned operations. A part, then, requires zero, one, or many planned operations or a pallet requires zero-one, or many planned operations depending on the shop order type. A planned operation requires zero, one, or many material callouts, special tool callouts, equipment callouts, and visual aids, and is used for production by zero, one, or many active operations.

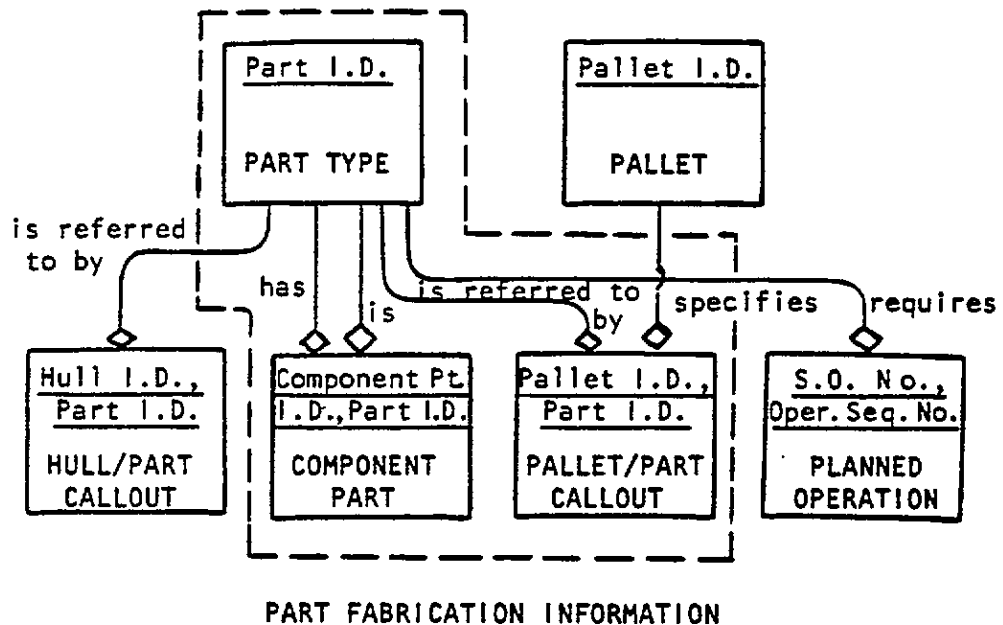


Figure 25. Part information to support outfit planning. A part type may have zero, one, or many component part types, and a part sometimes is a component part of some other part. A pallet and a hull both reference, or are comprised of, many parts so in order to have a bill of materials there must be a number of callouts to each part type. Also, for a fabrication-oriented shop order, each part type requires zero, one, or many planned operations. When a part requires several planned operations, it is called a fabrication process plan.

(Figure 26), they are for both part fabrication and assembly operations. Schedules set up for assembly require that parts be available for production, whether they are made in-house or by a vendor before they can come together into an interim product (i. e., pallet). So, it is necessary to know how long it will take to produce in-house parts. This information is attainable from the accumulation of individual planned operations or process plan. Once this is known, schedules based on precedence can be set up for production.

A unique aspect of the part type entity class is that it has two relationships with component parts. This does "not occur very often, but it simply means that a part type can have component parts and a part type can also be a component part at the same time. This is worth noting, but it does not greatly affect the data base design, rather it is an anomaly of the definition and use of the term part type.

4.4.6 Fabrication, Assembly, and Erection Monitoring Information (Figure 26)

In order to carry out and control outfit planning there needs to be actual production information which serves as a progress evaluation tool. Once the shop order is assigned a due date and a desired production quantity, it becomes important to monitor how well they are executed. A shop order production quantity is produced in one or more lots, especially for part fabrication, but it is also possible to assemble more than one pallet (i. e., when a unit is a standard assembly item). The distinction between an active and a planned operation is that the "active" operation is the actual process in action. This active process is for one particular lot of a shop order. The reason for having the information entity active operation tie together the lot and planned operation is for production traceability. In contracts where numerous contract amendments are made, their effect on production needs to be known. One way to do this is to see, in the case of a planned operation change, how many parts have already been produced and are being produced to the old specifications. Having this ability resident in a computer data base would provide much more control in determining the effects of an engineering or production change. In this design model a completed work ticket has been selected as the information entity class which reports progress to an active operation; however, there can be a variety of ways to actually report the job status.

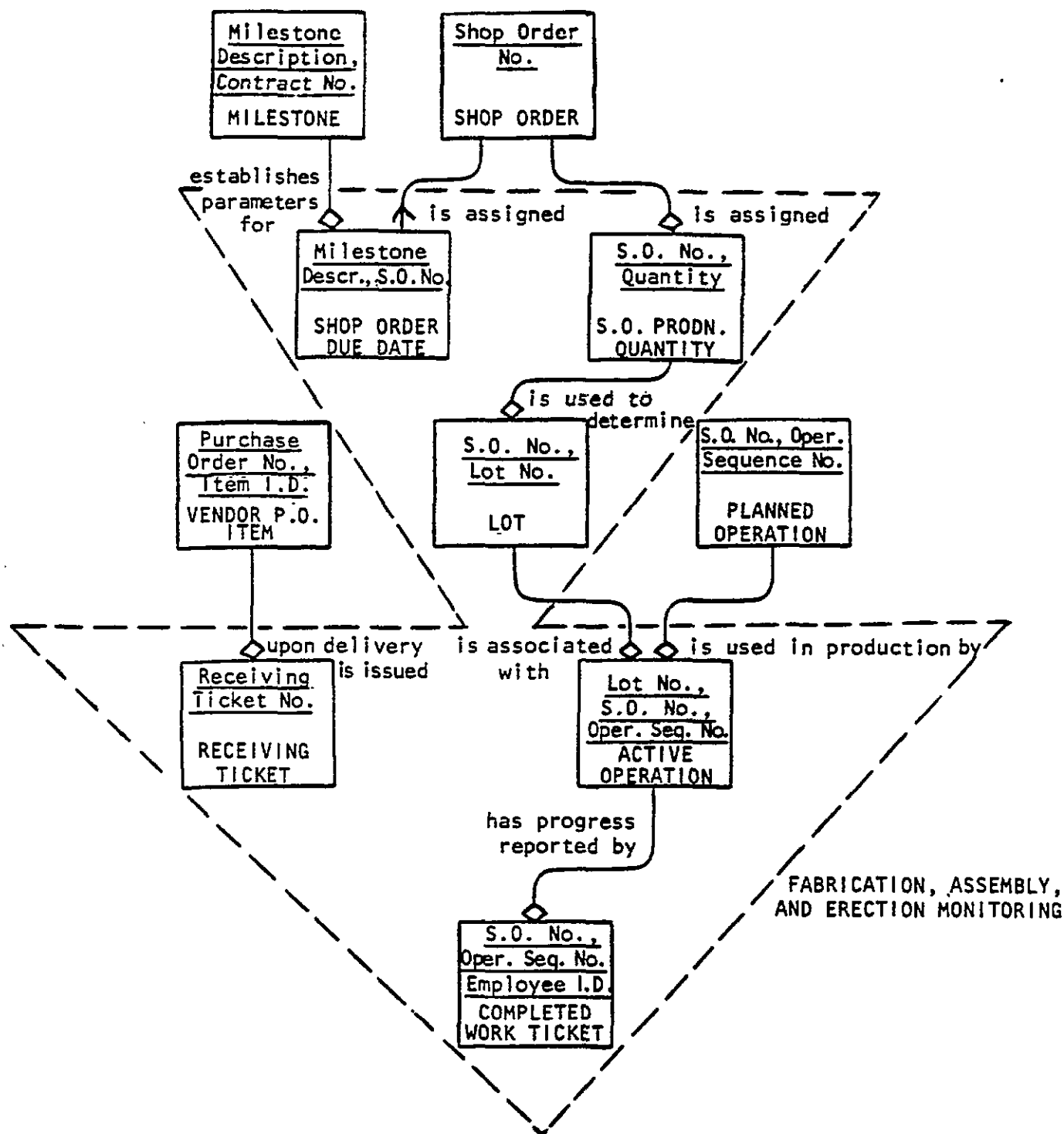


Figure 26. Fabrication, assembly, and erection monitoring which supports control necessary for outfit planning. A shop order is assigned a due date based on parameters set forth in a milestone. The milestone due data determines several shop order due dates. A shop order is assigned one or more production quantities (depending on whether it is a part or pallet S.O.) which in turn are broken down into one or more lots. A planned operation is used in production by zero, one, or many active operations, and each active operation is associated to a lot number with any particular shop order. The status of an active operation is usually reported by several completed work tickets. Procured materials are similarly accounted for by a receiving ticket.

Also, a link in the monitoring and control activity comes in the shipping and receiving department. In this case, the receiving ticket reports when a vendor purchase order item is in. This not only assists in monitoring vendor delivery commitments, but it also signals production control that an item (i. e., part) is in stock and available for production.

4.4.7 Procurement Information (Figure 27)

As discussed in Section 3.3, outfit planning provides a great opportunity for procurement to control and schedule purchases. By the same reasoning, however, it is important to realize that at least some basic information is needed from procurement in order to support outfit planning. The ability to relate shop orders to purchase order items provides two advantages to outfit planning. First, just as part fabrication and assembly processing times are needed to determine schedules, so are vendor delivery capabilities. Once estimates or formal vendor delivery schedules are set up, the impact on the rest of the production schedule can be determined. Long lead times always cause problems, but with the many work packages or pallets defined in outfit Planning work could be more easily rearranged to meet milestones than with the larger work packages of a system approach. Secondly, the ability to trace deliveries to the proper work package (shop order) is crucial to the pallet production concept. Instead of carrying such large in-house inventories, which is quite expensive, most of the material should be scheduled to arrive from the vendor "just in time" for the pallet to be compiled for assembly or production which saves inventory carrying costs. This means that specific items go to specific shop orders, and not only is a matching ability required, but also some way to record that a matchup did occur. So not only does outfit planning provides more control for procurement, but procurement needs to be more "controlled" in order to handle this extra attention to detail. There will be a lot less room for allowance (slop) in the system.

4.4.8 Overall Model (Figure 28)

Now that the information categories have been explained in detail, it is important to view the entire data base design model to gain a holistic systems perspective. The purpose of a data base is to provide storage and retrieval of information for an organization and in this case even more specifically for outfit planning. A data base design provides the structure or framework

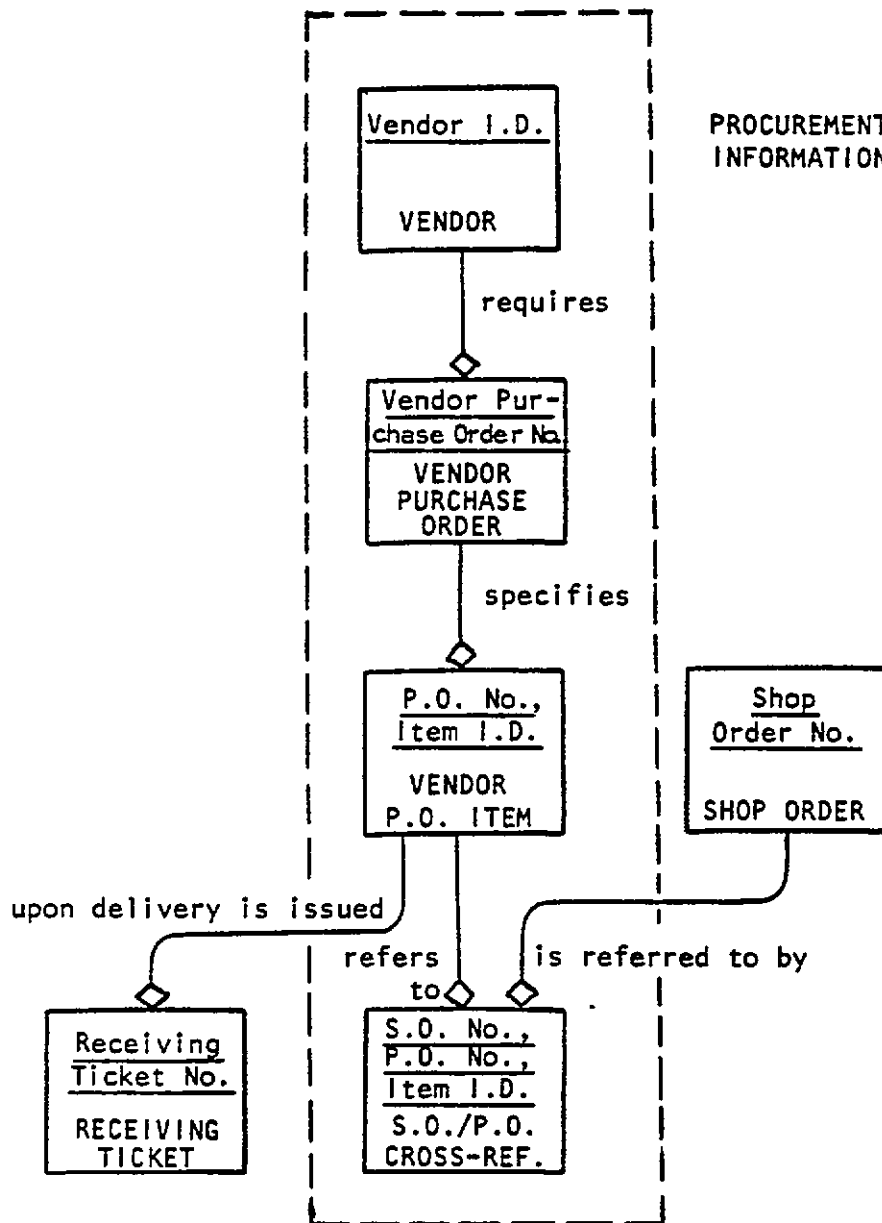


Figure 27. Procurement information supporting outfit planning in actual production. A shop order authorizes that a pallet be prepared. In the procurement activity it is important that materials purchased can be cross-referenced to the proper shop order. Conversely, it is important to production that they be able to assign incoming material to a specific pallet. This reads as follows: A vendor requires zero, one, or many purchase orders. A vendor purchase order may contain zero, one, or several items. Each item is issued a receiving ticket when it is accepted by the company, and each item is traceable to a shop order through a cross-reference file (e.g., bill of materials, procurement cross-reference lists).

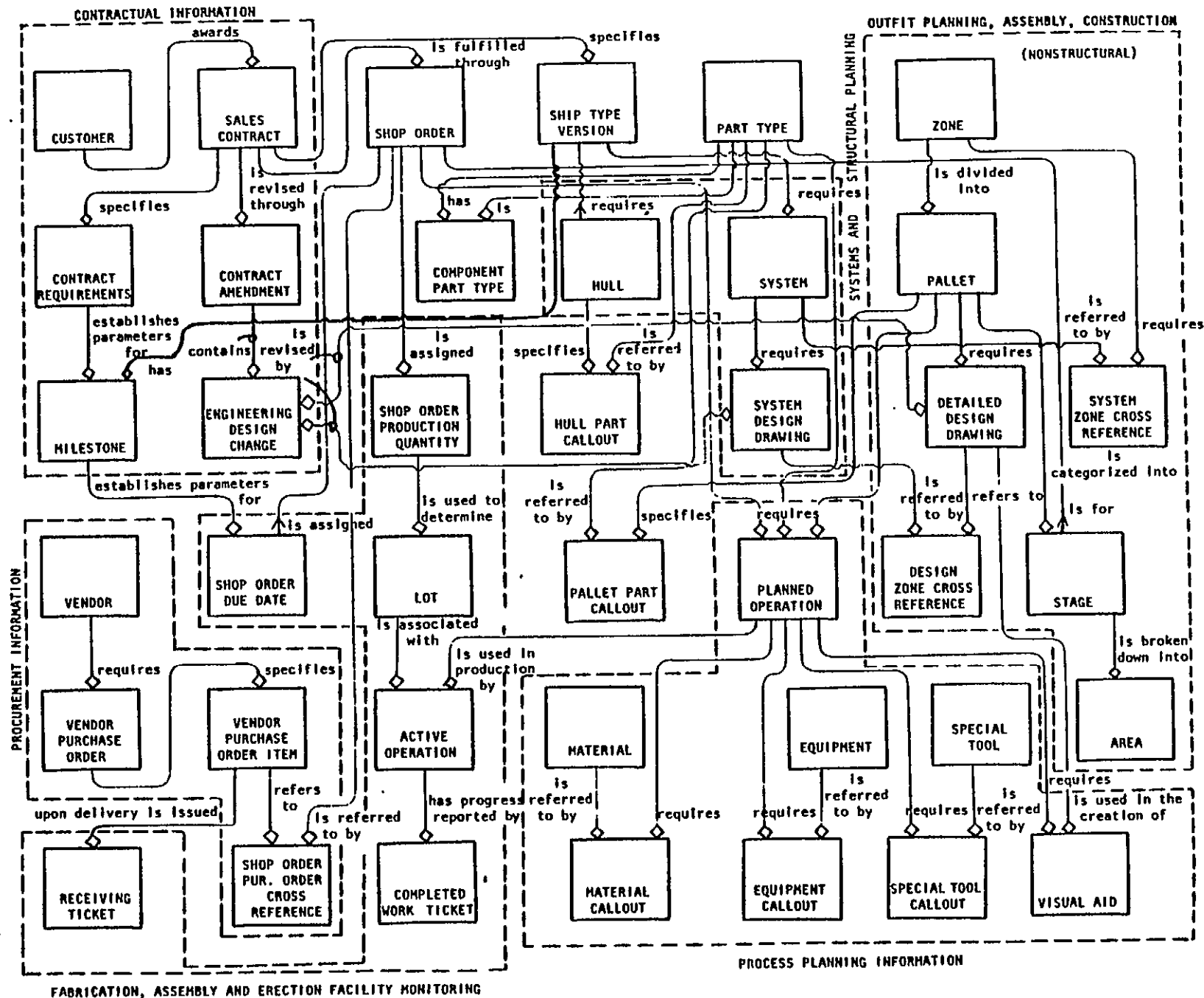


Figure 28. Overall conceptual design of a data base model for outfit planning.

around which information can be "filed away" and "reported back" in an efficient and cost-effective manner. To test the usefulness of a data base design, one must look through the eyes of the users of the system to see if their information needs are being met. One way to do this is simply to think up questions or "queries" that the data base would need to be able to provide information to answer. Some queries that this data base design model can answer are:

- How many contracts are there from any one customer
- How many ships are to be built per sales contract or per facility (what is the backlog)
- What are the milestones
- What are the contractual requirements
- How many contract amendments have there been on a specific contract
- How many contract amendments affected engineering and/or design changes
- How will an engineering/design change affect
 1. Design
 2. Production
 3. Procurement
- How many shop orders are there on a contract
- How many shop orders have been completed
- How many were finished on time, date, or early
- How many pallets are there in a ship type version, zone
- Have all the parts come in for a specific pallet
- Which systems engineering drawing were referenced in a detailed design drawing
- What is the material list for
 1. Total materials required
 2. Procured items
 3. Pipe shop
 4. A pallet
- How many pallets are on-unit, on-block, or on-board
- How many pallets are in a given area (production/problem area)
- How much fabrication work needs to be done
- How many direct labor hours to build the ship
- What kinds of materials, equipment, tools, parts, etc., are needed

- What is the overall ship construction schedule
- How many shop orders are being worked on right now.

The value of the data base design is worth the value management would place on the ability to answer important questions in a timely manner.

4.5 HOW TO FURTHER DEVELOP AND USE A DATA BASE DESIGN MODEL

A data base design and a data base management system (DBMS) need to be distinguished for a full perspective on the computer information handling environment. A data base design sets up the filing structure and information entity relationships, and a DBMS is required to actually administer that structure and manage those interrelationships. A DBMS can be described as a software system devoted to the management of interrelated data collection.²⁶ In this context, then, the data base design is the definition of those data collections and interrelationships. In the filing cabinet example in Section 4.2 the file clerk acts as the DBMS, whereas the content of the filing cabinet drawers and the relationship of one drawer to another are the data base design. It *is* much more important to have a well-organized filing system (data base design) than it is to have a speedy file clerk (DBMS). This does not suggest that a DBMS is not important, because at some point the two have to work well together or the overall system will suffer.

The data base design which has been described in this report is independent of any DBMS. This means that it can be incorporated into most DBMS's without major entity redefinition or relationship changes. The design model provides a conceptual framework around which the actual information can be fed into it. Once it is defined in detail, a DBMS which best suits it can be selected.

This high level data base design model for outfit planning provides the first step in seriously analyzing the information environment of a shipyard. The next step would be to develop a detailed data base design model (which would probably be two to four times the size of this one) preferably geared to implementation in a specific shipyard, though a generic detailed model could be established. Then the physical environment for an actual prototype system must be defined. The conceptual modeling technique does well up until an actual implementation plan needs to be established. At this point statistical analysis and specific data base management systems need to be used and decided

upon, respectively, before the data base is actually built. The physical parameters of a data base are fairly easy to conceptualize. They involve finding out how many "files" go in the drawer (how much data goes into an entity class) and which drawers are used the most and which relationships are the most important. It would be quite feasible to actually simulate and perform statistical analysis on this for an actual shipyard. Depending on the detailed design of the data base, the DBMS choices should be narrowed down. Each DBMS has its strengths and weaknesses, and based on the statistical analysis, the DBMS should be chosen which most cost effectively correlates to the most important features of the data base design.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 GENERAL CONCLUSIONS

If the goal of the American shipbuilding is to increase the competitive position, then the objectives should be to increase integration of design, material procurement, and production to effect an increase in productivity.⁸ And according to the recent technology survey, "a number of the high technology foreign shipyards have invested heavily in specialized facilities not suitable for a wide product mix with few similar ships. With the current depressed state of world shipbuilding, an opportunity to leapfrog these highly specialized foreign shipyards with more versatile U.S. shipyards may be present."¹³ To make such a move brings forth several areas of concern.

5.1.1 Management Attitudes

The first area of concern is the attitude of management toward change. Managing change is perhaps the most difficult of management responsibilities because it places a company in "unknown waters" which requires highly organized planning and the "ability" to forecast into the future. To minimize the risk of individual shipyards there would need to be a willingness to work together with other U.S. shipyards for mutual, long-range benefits. This would mean also that they would have to share data (on a controlled basis, of course) significant enough to build trust and further the industry as a whole. One suggestion for this is in Section 5.6, Coordination of Advisory Groups.

5.1.2 Implementation of Improvements

It would be disastrous to simply incorporate foreign shipyard techniques into U.S. shipyards and expect them to be competitive again. At best, the United States would be no better than the competition and odds are that not all their techniques would fit into U.S. shipyards. The real key is to rethink shipbuilding totally, not just copy the Japanese (for example). The United States needs to understand the ideas and methods of other nations, and then build on them, without hesitating to go on an entirely different route. For any given problem, several solutions may be right from a competitive or bottom-line point of view.³⁰

5.1.3 Improve Areas of Leadership

The United States has some areas of technology leadership, Section 2.4.2, which it should exploit on shipbuilding wherever practical. These are computer hardware, software, and communications, as well as industrial and manufacturing engineering methodologies. The United States is an innovator of most new technologies, but trails in application of it. There exists a strong need to become better implementers of these techniques.

5.1.4 Maintain and Improve Standoff Areas

As far behind as U.S. shipyards are in general design and construction methods, U.S. vessels are still on a par with other nations in terms of quality and product technology. In fact, the only real areas that the United States can still compete in effectively are highly complex ships such as LNG (liquid natural gas) tankers and defense ships. In general, the materials and process technologies are also comparable to foreign countries. The U.S. shipbuilding industry needs to maintain and improve these areas and possibly consider them as crucial to the overall effectiveness of any competitive strategy.

5.1.5 Recover Areas of Japanese Leadership

The recovery area will simply be listed, since they have been covered before in this study.

- Long-range planning versus short-term management
- Cooperation between industry, government, academia, and financial institutions
- Human resource management; participative orientation
- Methodical attention to detail and quality
- Integration of design and production
- Utilization of the product work breakdown structure (transition design) as a common technical framework for design, planning, materials acquisition, and production
- Improved communication and relationship with material/equipment suppliers.

5.1.6 Coordination of Many Advisory Groups

One area which could be of great benefit is the ability to coordinate, consolidate, and communicate information and efforts of the National Ship-

building Research Programs (NSRP), the Shipbuilding Technology Program (STP), the Shipbuilding Production Committee (SPC), Institute for Research and Engineering for Automation and Productivity in Shipbuilding (IREAPS), Manufacturing Technology (MANTECHS) projects, other Societies of naval architects and marine engineers (SNAME), National Academy of Science efforts, and finally, the shipyards themselves. All of these have relevant information for improving productivity in shipyards, but a real in-depth recovery plan would have to transcend and incorporate them into an overall strategic Plan for the industry.

5.1.7 Taking Advantage of TECHMODS

A new "business deal" from the Department of Defense is called a technology modernization (TECHMOD) contract. A TECHMOD tries to make up for the usually no-incentive contracting procedures by allowing the government and the industry to share in the profits of any new methods which will enhance productivity. They are geared to minimize (not eliminate) the risks of capitalization and new technology implementation for the contractor as well as provide profit incentives to modernize. Shipbuilding firms which are serious about modernizing and are working on government contracts should use TECHMODs wherever possible. Policy makers should consider similar business deals for commercial ship construction instead of previous, ineffective policies which have only served to tamper with the free market directly.

5.2 GENERAL RECOMMENDATIONS

The proposed approach to a viable recovery strategy for the U.S. shipbuilding industry would involve creatively rethinking the entire shipbuilding process as it currently exists. To do this requires an in-depth knowledge of technological and philosophical differences between the United States and other countries, a good grasp of current state-of-the-art technologies available, and understanding and insight into the future demand for ships and the overall competitive situation.

Before the industry can rethink the shipbuilding process, they will need to have a full in-depth understanding of how they currently operate. It seems incomprehensible that no one person or no one group of people needs a full-in-depth understanding of their own current operations, but it simply is not essential to making a facility work. Without getting into organizational

behavior theory, simply picture each person, direct laborer through general manager (or president, if desired), having a sphere of influence on the company and a given set of responsibilities. Some of these responsibilities totally overlap such as two welders, whereas other responsibilities overlap only slightly with many others, such as a department manager over several foremen or a general manager over several department managers. Each person is charged with the task of doing the best that can be done, but no one perspective covers the facility as a whole. Again, this holistic perspective is not essential to making a facility work, but it is essential to making a facility work best. This lack of holistic perspective seems to be true for most industry in general, not just shipbuilding. What is required is a way to cut across responsibility lines of an organization and simply look at the activities involved (regardless of who does them) from the perspective of a technical and economic analyst. Such an approach would achieve a full in-depth view of the facility.

An in-depth functional model or structured analysis, such as the ones at the beginning of this report (but in much greater detail), is one good method to do this. Functional breakdowns have been used to explain processes for as long as structured engineering methods have existed, such as in Figures 29 and 30. The only difference in this proposed approach is to view a much bigger system that represents the whole shipbuilding process instead of one that just addresses production processes.

Once this is done, the industry can brainstorm, evaluate, and suggest future goals which they wish to achieve. Finally, the task becomes one of developing a practical time-phased implementation strategy.

For example, one approach might be to extend the product work breakdown (PWBS) ⁹ to encompass the whole shipbuilding process--call it the Task Work

- In fact, if integration of strategic planning and information resource management (IRM) systems is a sign of a holistic viewpoint of a company, then only 19% of 40 "Fortune 500" type companies surveyed have done so, according to an A.T. Kearney, Inc. management consultant survey. This same survey reveals that those companies that did integrate strategic planning and IRM out-performed the others by 300% (in terms of average return on equity, return on total capital, and new profit margins).

LEVEL I MASTER CONSTRUCTION PLANS OR KEY EVENTS	LEVEL II AREA OR SYSTEM PLANS	LEVEL III WORK PACKAGES	LEVEL IV MANUFACTURING OR FABRICATION ORDERS
SHIP/TASK DEFINITION			
<ul style="list-style-type: none"> • Contract Design & Spec. • Drawing List • Arrangemt. Drwgs. 	<ul style="list-style-type: none"> • Detail Functional Design • Classification Drwgs. & Specs. • Drwg. Dev. Plan • System Drwgs. 	<ul style="list-style-type: none"> • Working Design • Work Package Drawings 	<ul style="list-style-type: none"> • Manufacturing Sketches
BUILDING METHOD AND SEQUENCE			
<ul style="list-style-type: none"> • Contract Milestones • Preliminary Construction Plan 	<ul style="list-style-type: none"> • Outfitting Work Plan • Work Pkg. Breakdown • Test Plan • Plan for Subcontracting 	<ul style="list-style-type: none"> • Work Package Scopes • Compartment Work Lists • Test Memos 	<ul style="list-style-type: none"> • Manufacturing Work Orders • Manufacturing Work Order Routing
MATERIAL ALLOCATION			
<ul style="list-style-type: none"> • Preliminary Material List • Procurement Plan 	<ul style="list-style-type: none"> • System Material List • Procurement Plan 	<ul style="list-style-type: none"> • Work Package Material List • Procurement Plan 	<ul style="list-style-type: none"> • Manufacturing Work Order Material List
MANPOWER ALLOCATION			
<ul style="list-style-type: none"> • Preliminary Manpower Allocation • Shipyard Loading 	<ul style="list-style-type: none"> • System Manpower Allocation • Shop Manloading 	<ul style="list-style-type: none"> • Work Package Manpower Allocation • Shop Manloading 	<ul style="list-style-type: none"> • Manufacturing Work Order Allocation • Work Center Manloading
FACILITY ALLOCATION			
<ul style="list-style-type: none"> • Facility Plan • Shipyard Loading 	<ul style="list-style-type: none"> • Shop loading 	<ul style="list-style-type: none"> • Shop Loading 	<ul style="list-style-type: none"> • Work Center Loading
DURATION ALLOCATION			
<ul style="list-style-type: none"> • Durations Between Milestones 	<ul style="list-style-type: none"> • Outfitting Work Plan Event Durations 	<ul style="list-style-type: none"> • Work Package Durations 	<ul style="list-style-type: none"> • Manufacturing Work Order Durations

Figure 29. Functional elements of outfit planning.¹⁷

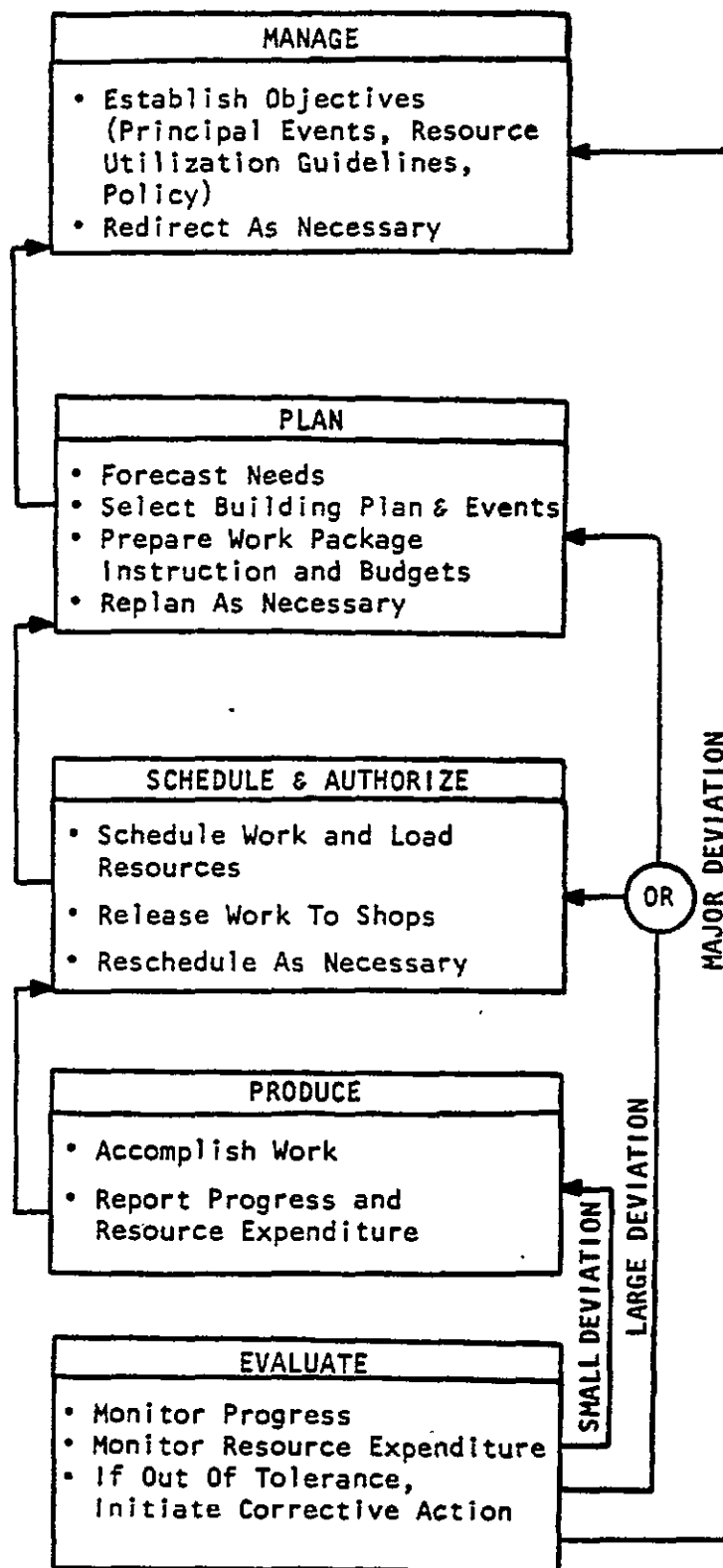


Figure 30. Planning and scheduling in the management cycle.¹⁷

Breakdown Structure (TWBS). In future shipbuilding facilities, similar functions might be grouped together such as managing the business, all product related work, such as design and Process planning, and all the actual "doing" or production processes together. Maybe the new structure would look like 'Figure 31, Shipyard Management. To see if this looks viable each task would be broken down further and checked for fit as in Figure 32, Operations Management.

Once goals are set, then comes the very critical task of setting attainable objectives and implementing improvements which will work toward achieving these goals. Much depends on the ability of the shipbuilding industry to perform relevant long-range planning. Many, of the philosophical differences in production processes, such as assembly sequence, are changes that can be made without major capital investment. Some ways to improvement do, of course, require substantial investments in facility and equipment, such as increasing crane lift capacity or increasing space for assembly work. But regardless of the type of improvement, it must be an integral part of a long-range plan or it may very well only stifle productivity in the long run. Many industrial and government projects have poured money into development of new technologies which were then neglected (not implemented) in the United States only to find that other nations are now exploiting it to U.S. disadvantage. "Islands of technology" are great for scientists, but application of leading edge technologies into an integrated long range competitive strategy is where the U.S. economy will be bought and sold.

5.3 OUTFIT PLANNING CONCLUSIONS

Outfit Planning provides a great potential to reduce manufacturing costs and improve production schedules. It is possibly the single most important method/philosophy which a U.S. shipyard can incorporate to achieve productivity gains. It will take the strong leadership from upper management and a commitment by the whole facility staff to implement it effectively. Long-range strategic planning backed by effective tactical and implementation Planning are paramount to successful changeover from systems-oriented to a production-oriented detail design. The pallet concept is the key ingredient to production-oriented design, procurement scheduling, and production ,process planning, control, and scheduling. Focusing on the similarities from ship, to ship through outfit planning should produce a learning *curve* effect which con.

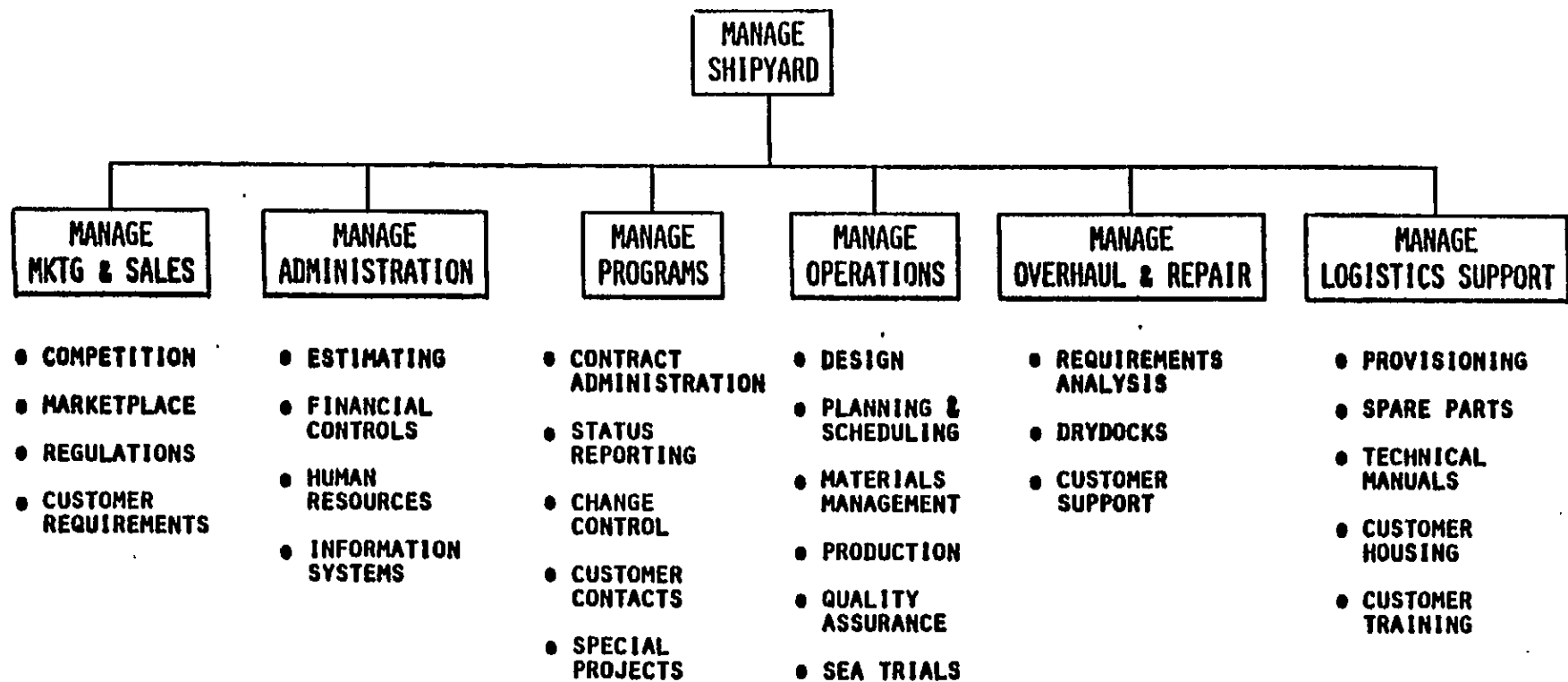


Figure 31. Shipyard management via a task work breakdown structure (TWBS).³¹

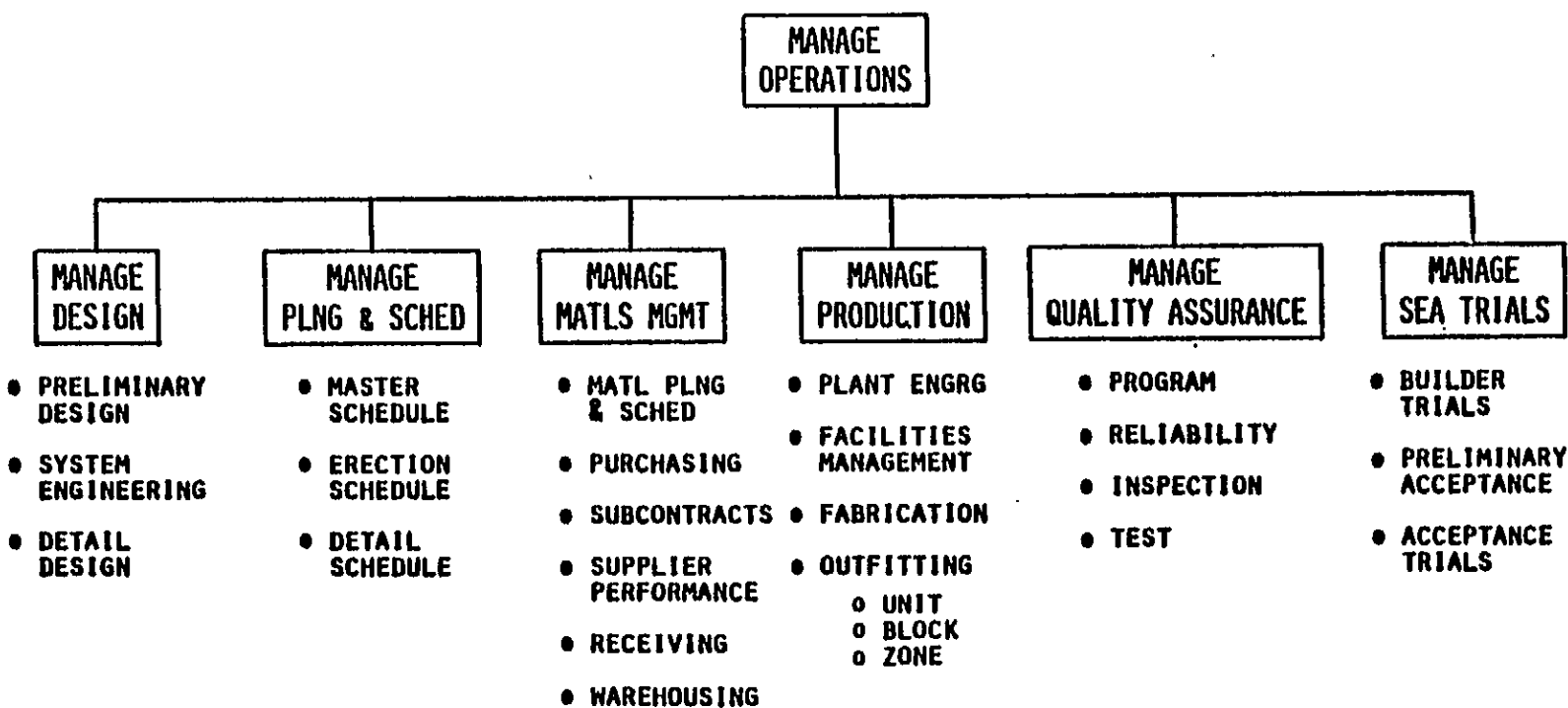


Figure 32. Operations management via a task work breakdown structure (TWBS).³¹

ributes immensely to increased design and production control and to standardization, and will reduce ship production schedules and costs. It is anticipated that a total cost savings of 25% could be realized in labor and material cost savings alone.

5.4 OUTFIT PLANNING RECOMMENDATIONS

Again, it must be emphasized that even though outfit Planning may provide the largest single improvement in shipyard productivity, it would not be enough, by itself, to make a U.S. shipbuilder competitive on the world market. A holistic approach which incorporates outfit planning and other improvements is recommended, as suggested in "Section 5.2. If outfit planning were to be incorporated singly, the function approach recommended in Section 5.2 would still apply, though possibly on a smaller scale.

5.5 OATA BASE DESIGN CONCLUSIONS

A data base is dependent on what a company desires to use information for and how they wish to access that information. An effective data base design for support of outfit planning must relate information directly to design engineering and must also be accessed by procurement, production control, process planning, structural planning, material handling, and quality assurance. The most flexible data base designs attempt to maximize information/data independence, nonredundancy, reliability, integrity, accessibility, and shareability. Using a logical sequence of design steps and a conceptual (graphic) modeling technique will produce a data base design of this type which ensures that the basic systems requirements are met and that **system** evolution will be consistent as demands and technology changes affect those requirements. This study has produced a conceptual data base design model which covers all of the important information issues that affect outfit planning at a high level. A much more detailed model could be developed using the concepts established in this **study** as a cornerstone.

The importance of timely and accurate information to the proper functioning of a company cannot be overemphasized. Information and communication are the underlying supports to every activity of a company and Figure 33 illustrates that a data base (information) is the central element which binds the other activities together. It is for these reasons that flexible and

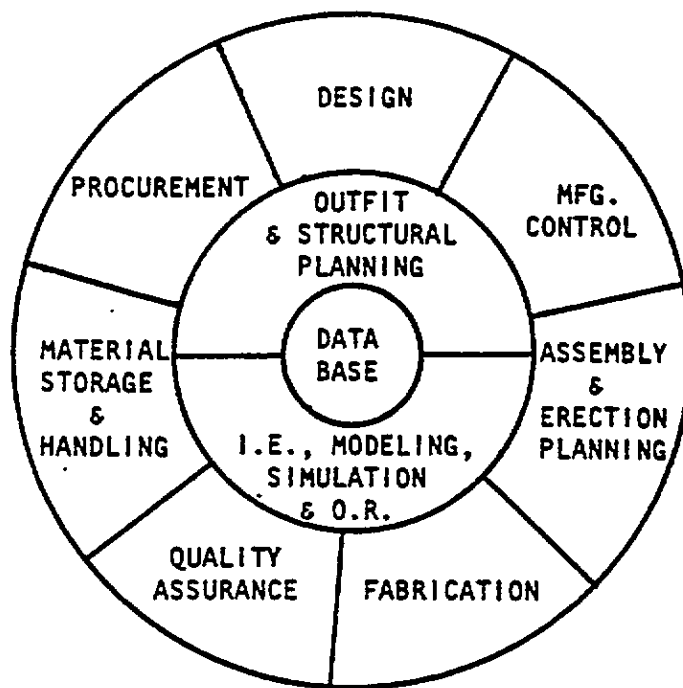


Figure 33. Shipyard activity wheel. A common or central data base can provide the support necessary for an integrated approach to all the activities of a manufacturing concern. For a shipbuilder, outfit and structural planning are key tasks with overall support from industrial, manufacturing, and systems engineering and their associated tools of simulation, modeling, and operations research. Planning and engineering provide the basis by which the actual or physical "doing" of ship production is accomplished (the seven outer tasks). Information and communication provide means by which all decisions are made and therefore represents the core or cornerstone of an effective organization.

thorough data base design techniques must be used to support a major company undertaking such as outfit planning. In fact, outfit planning provides the justification for developing such an elaborate system.

5.6 DATA BASE DESIGN RECOMMENDATIONS

There are three possible avenues to pursue in developing a more detailed data base design to support outfit planning.

5.6.1 Develop a Generic Shipyard Data Base Design

The first alternative is to develop a detailed data base design model based on an in-depth study of several representative shipyards. This model would be "generic" in the sense that all information requirements of the study of the shipyard would be incorporated into the model, as it applies to outfit planning. This may even include an in-depth analysis of a Japanese shipyard, such as one of IHI, to use as benchmark since it would be the only actual fully outfit-planning-oriented operation studied. This requires a large level of effort, but the end result would be a very thorough model which could be applied with minor modification by any U.S. shipyard. A prototype data base should be built and tested with actual ship design and production data, or at least simulated.

5.6.2 Develop a Company-Specific Data Base Design

Since a few U.S. shipyards are already involved in implementing many of the aspects of outfit planning, a study could be done that develops a company-specific detailed data base design model. The model is much more company-specific in this case, but if the proper modeling methodology is used (like the one in this study), the results can be beneficial to the U.S. shipbuilding industry in general. Other shipyards, with some effort, can take this company specific model and modify it to suit the needs of their facility.

5.6.3 Encourage Development to Occur Individually

The conceptual data base design developed in this study is a sound baseline for an individual shipyard to begin planning for outfit planning information requirements. In this context, it may be adequate simply to encourage those shipbuilders who are implementing outfit planning concepts to develop their own detailed data base design models. Since this requires a reasonably large level of effort, there should be some incentives provided to encourage a

thorough job. If the information is available to the public domain, it greatly reduces the types of funding assistance and the contribution to the industry in general. Nondisclosure could be accomplished (1) for defense work through a TECHMOD (business deal) by allowing data base design to be included as one of the joint funding ventures of technical modernization, and (2) for a commercial shipyard, where joint funding for IREAPS members is possible if their suggestions are approved, though this would involve some information dissemination to the IREAPS member company. Other possibilities may exist for nondisclosure, but these two are the most obvious.

The best choice of the three development recommendations simply depends on the objectives of the funding agency or shipyard(s) that have an interest in pursuing it. The most beneficial approaches in a U.S. shipbuilding capabilities sense are those which disseminate the project results to the industry as a whole.

5.7 SUMMARY OF CONCLUSIONS

There is nothing that other shipbuilding nations have done that the U.S. shipbuilders cannot do. In fact, most of the productivity differences have not occurred "cataclysmically," all at once, but rather have evolved over a period of time. By the same reasoning, for the United States to regain a favorable competitive position will take a number of years. To illustrate this evolution, the following list summarizes many points of "Japan's Phenomenal Shipbuilders":

What has Japan done right:

- o Rationalization of shipyard procedure
- Luxury of large dry docks (coincidence?)
- World War II necessities
 - block assembly systems
 - semi automated welding
 - advanced fitting-out
 - standardization
- o Time for engineers to rethink the processes (recession between 1946 and 1954)
- o Introduced by a U.S. firm
 - assembly line methods
 - prefabrication of large sections
- o Diversification into related fields
- o Economical hull forms (bulbous bows)

- Thinner steel plate
- Large cranes (large load capacity)
- Constant infusion of engineers (700 per year).

None of these methods by themselves were incredibly ingenious, even though some (if not many) of the applications were imported from the United States. So the shipbuilders of Japan are phenomenal not through the use of some secret productivity weapon, but rather they are phenomenal because they have effectively and efficiently managed their operations, paying particular attention to detail and emphasizing good engineering practices--something that many U.S. shipbuilders and many U.S. companies in general have not done well in the past. There are no real barriers to stop U.S. shipyards from excelling in the future. A recession can be a good time to rethink and reorganize, and many U.S. shipbuilders are already on the road to recovery. It is the hope that this study will contribute to that end by explaining and defining the high level information/data base requirements needed to support outfit planning.

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APPENDIX

DATA BASE , DESIGN MODEL GLOSSARY

DATA BASE DESIGN MODEL GLOSSARY

ACTIVE OPERATION

A planned operation which is in use for a specific lot. Knowing which lots are in operation and which particular operation they are on will help determine if contract amendments are feasible or if rework, completion by the old specifications, or scrapping is necessary. If the latter is true, it could affect costs, etc. Active operation provides the current status of a customer sales contract.

AREA

Area is a production process category used to specify **what** general type of work a pallet **needs. It** might suggest special handling equipment, etc.

COMPLETED WORK TICKET

A time card which has been filled out by a worker after the worker has carried out an operation as completely as possible.

COMPONENT PART TYPE

A subpart or assembly piece of a major part type.

CONTRACT AMENDMENT

A contractual agreement changing the terms and conditions of the sales contract.

CONTRACT REQUIREMENTS

Single (numbered) paragraph of the contractually defined requirements describing the total end-item products, or ships which are to be delivered to the customer and the terms and conditions under which the customer will accept the delivery.

CUSTOMER (Contractor, (Client)

This is any firm which may be, has been, or could be a contractor of goods and services.

DETAILED DESIGN DRAWING

A graphic representation of a pallet which reflects its geometric configurations, dimensions, and construction (form, fit, and function).

ENGINEERING/DESIGN CHANGE

Reflects the occurrence of a revision to an engineering requirements or design.

EQUIPMENT

Capital equipment which have certain characteristics in common, thereby allowing them to be grouped together, usually function and/or capability.

EQUIPMENT CALLOUT

An operation is usually planned with a particular machine type in mind, and this machine will be specified on the actual production instructions.

HULL

The frame or body of a ship not including masts, yards, sails, and rigging.

HULL-PART CALLOUT

The cross-reference which identifies which parts belong to the hull. All callouts combined for a hull could be considered a hull bill of materials list.

LOT (Production lot, **Job**, Batch)

A uniquely identifiable quantity of a specific part or pallet traceable to a shop order. Due to frequent contract amendments, lots are usually made to a specific drawing so that the specifications (tolerances, inspection requirements, etc.) can be traced, if necessary.

MATERIAL

Material and standard parts in an as-received condition. This can be bar stock, castings, forgings, etc. This material may be customer supplied or purchased from a vendor.

MATERIAL CALLOUT

The occurrence of a specific requirement for material, i.e., material in an "as-purchased" condition.

MILESTONE (Preliminary Master Schedule Item)

A significant selected scheduled event or task in the performance of a contract.

PALLET

A pallet represents a work package consisting of 40 to 120 person-hours worth of work for two or more workers.

PALLET-PART CALLOUT

A pallet-part callout identifies the parts required to build/assemble a pallet.

PART TYPE

A physical product which is uniquely identifiable from other products based on its individual characteristics, which typically include form (shape), fit (dimensions), function (componentry), quality (the standard or specifications it conforms to), etc. Typically, each part type is assigned a unique part number.

PLANNED OPERATION

A uniquely identifiable step intended for use in the manufacture of a part, normally performed within a single work station. Operations include fabrication and assembly steps, as well as inspection steps.

RECEIVING TICKET (Receipt)

The acknowledgment" that materials, tools, or Parts have arrived. These are usually customer/vendor **supplied**, but can be issued for internally manufactured special tool in to cue the production control supervisor that the item *is* available for production.

SALES CONTRACT (Contract)

A binding agreement" to establish conditions of performance and obligation between customer and shipbuilding contractor.

SHIP TYPE VERSION

Refers to a specific ship identified by a type version number.

SHOP ORDER

This is the internal accounting vehicle the company uses to identify an active sales contract and monitor its progress. The shop order part and pallet are the most important identifiers of work at the production site.

SHOP ORDER DUE DATE

The time at which a shop order is scheduled to be completed.

SHOP ORDER PRODUCTION QUANTITY

This is the quantity desired for production based on the purchase order delivery schedule and quantities which are produced in one or more lots.

SHOP ORDER. PURCHASE ORDER ITEM CROSS-REFERENCE

(Abbr: S/O, P/O X-Ref. ")

Traces a specific purchase order item to the appropriate shop order. Also provides traceability of a receiving ticket to a shop order.

SPECIAL TOOL

A device which has been specially designed (and serialized) to be used in conjunction with a machine or by hand to aid in the production and/or inspection of parts.

SPECIAL TOOL CALLOUT

The requirement for a special tool type which should be **used** in the performance of specific work defined by the planned operation.

STAGE

This is the processing stage of production that a pallet *is* assigned to at any point in time. These are usually on-unit, on-block, or on-board.

SYSTEM

Various systems within a ship such as ventilation, piping, structural , etc.

SYSTEMS ENGINEERING DRAWING

A graphic representation of a ship system which reflects its geometric configuration, dimensions, and construction (form, fit, and function).

SYSTEM-ZONE CROSS-REFERENCE

This is a cross-reference in which a system can run through various zones of ship.

VENDOR (Supplier)

A manufacturer or distributor which is available to supply a company with goods and *services*.

VENDOR PURCHASE ORDER

This relates to the acquisition of goods and/or services to a supplier of these goods and/or services. This can be used for raw material , operations/processing, component parts, and/or tooling.

VENDOR PURCHASE ORDER ITEM

This is an item specified on the vendor purchase order which could be for materials, tools, and/or processing.

VISUAL AID

This is a drawing illustrating a production, inspection, assembly, or set-up operation which only shows the detail necessary to specifically carry out an operation.

ZONE

Geographical sections of a ship. Usually these are accommodations, deck, machinery, and electrical.